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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

D3.1 Delivery of climate data and indicators

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

Lead beneficiary: Fondazione CMCC

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1 Introduction

This document provides a short description of the climate data (about 2 TB) delivered by CMCC to the ICARUS project users, covering the period from 2006 to 2065 following two different possible scenarios for the XXI century. High resolution (order of 10 km) meteorological fields (temperature, wind, precipitation among others) are made available in a common format over the European domain to the ICARUS partners. Also, boundary conditions at lower spatial resolution (order of 200 km) are provided, for dynamical downscaling purposes up to 1 km over 9 ICARUS selected cities.

A set of four Regional Climate Models (RCMs) participating to the EURO CORDEX project on the EUR-11 (about 10 km resolution) horizontal domain has been evaluated and the relative high resolution daily output have been made available to the ICARUS project users. In addition, in order to provide boundary conditions for downscaling purposes, also lower resolution General Circulation Models – GCMs (see next section) results at the 6 hourly time frequency have been provided. After a preliminary evaluation of the CPU time needed for the ICARUS downscaling effort, we decided to focus on a single downscaling model realization, forced by one GCM over two different scenarios (RCP45 and RCP85). The GFDL-CM3 model has been chosen based on its ability in representing the European Climate: 6 hourly boundary conditions for dynamical downscaling over a pre-defined subdomain have been then made available.

2 Model and numerical simulations description

The performance and the spatial resolution of General Circulation Models (GCMs) have continuously improved in the recent years, but the typical state of the art spatial scale is still too coarse to realistically reproduce present climate and eventually project climate change signals on local scales, especially in the presence of complex orography (Rummukainen, 2010; IPCC, 2001). Therefore, in order to improve the description of the small-scale processes and their effects on climate, dynamical downscaling is performed using limited area - very high resolution models, implemented on the domain of interest. In addition to the provision of high resolution climate data for analysis purposes, a first approach we wanted to apply for dynamical downscaling was to provide to ICARUS modelling group also high horizontal resolution boundary conditions from the EURO-CORDEX (COordinated Regional climate Downscaling EXperiment) (Nikulin et al., 2012) on the 10 km EUR-11 (Figure 1) spatial domain. To this aim a first assessment of the EURO-CORDEX RCMs performances in representing the European climate has been done together with a comparison with GCMs results (see section 3), at a lower resolution, and observations. We finally decided to use GCMs to provide boundary conditions to ICARUS downscaling group, because of the less pronounced biases when compared to the observations and the higher temporal resolution available (up to 6 hourly). On the other hand, the high resolution EURO-CORDEX data have been made available for ICARUS partners not involved in downscaling effort. The following subsections describe the RCMs (2.1) and GCMs (2.2) together with the considered future scenarios definition (2.3).

2.1 *The EURO-CORDEX Regional Climate Models*

EURO-CORDEX is the European branch of the international CORDEX initiative, which is sponsored by the World Climate Research Program (WRCP) to organize an internationally coordinated framework to produce improved regional climate change projections for all land regions world-wide (http://www.euro-cordex.net/). The CORDEX-results serve as input for climate change impact and adaptation studies within the timeline of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and beyond. The experiments used to provide the RCM dataset described in this report are based on the standard setup of the model for the CORDEX (COordinated Regional climate Downscaling EXperiment) ensemble simulations (see e.g. Table 1 of Nikulin et al., 2012, Vautard et al. 2013) over the EUR-11 domain (Figure 11).

Four RCMs have been considered, based on the availability of a sufficiently high number of climate parameters at the higher time frequency (daily). Table 1 lists the considered RCMs. In Table 1 the list of the driving GCMs, furnishing boundary conditions to the relative RCM is also provided.

Thanks to these models a series of meteorological parameters, listed in Table 2 has been collected and made available to ICARUS partners.

Table 1: Regional Climate Models involved in ICARUS data collection.

Model name	**Driving GCM**	**Institute**
SMHI-RCA4	CNRM-CM5	Swedish Meteorological and Hydrological Institute, Rossby Centre
KNMI-RACMO22E	ICHEC-EC-EARTH	Royal Netherlands Meteorological Institute
INERIS-WRF331F	IPSL-CM5A-MR	IPSL (Institut Pierre Simon Laplace) and INERIS (Institut National de l Environnement industriel et des RISques)
CNRM-ALADIN53	CNRM-CM5	Centre National de Recherches Meteorologiques

2.2 *The CMIP5 General Circulation Models*

Under the World Climate Research Programme (WCRP) the Working Group on Coupled Modelling (WGCM) established the Coupled Model Intercomparison Project (CMIP) as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access. This framework enables a diverse community of scientists to analyze GCMs in a systematic way.

Coupled atmosphere-ocean GCMs allow the simulated climate to adjust to changes in climate forcing, such as increasing atmospheric carbon dioxide. Different simulations are defined, from preindustrial, to historical and future scenarios (see next subsection).

The GFDL-CM3 model, the one we decided to use to provide boundary conditions for ICARUS downscaling, is one of the most reliable GCMs in representing the European Climate within the CMIP5 model list (McSweeney et al. 2015). GFDL-CM3 climate model (Donner et al. 2011) has been developed to study climate change, and the coupling between the troposphere and stratosphere. The model is designed to serve as the physical system component of earth system models and models for decadal prediction in the near-term future—for example, through improved simulations in tropical land precipitation relative to earlier-generation GFDL models. For a deep description of dynamical core, physical parameterizations, and basic simulation characteristics of the atmospheric component (AM3) of this model we redirect the reader to Donner et al. (2011). The model includes new treatments of deep and shallow cumulus convection, cloud droplet activation by aerosols, subgrid variability of stratiform vertical velocities for droplet activation, and atmospheric chemistry driven by emissions with advective, convective, and turbulent transport. GFDL-CM3 atmospheric component (AM3) employs a cubed-sphere implementation of a finite-volume dynamical core and is coupled to LM3, a new land model with ecosystem dynamics and hydrology. Its horizontal resolution is approximately 200 km, and its vertical resolution ranges approximately from 70 m near the earth's surface to 1 to 1.5 km near the tropopause and 3 to 4 km in much of the stratosphere. Most basic circulation features inAM3 are simulated as realistically, or more so, as in the previous version AM2.

2.3 *The simulations*

In addition to the historical simulation, two future emission scenarios have been considered among those developed for the last IPCC assessment report, to provide data to ICARUS users covering the period 2005-2065. Specifically the RCP8.5 (Representative Concentration Pathway 8.5), considered as a sort of worst case in terms of radiative forcing and the RCP4.5, considered as a more moderate scenario (Riahi et al. 2011, Taylor et al. 2012), have been selected within the ones available from the Coupled Models Intercomparison Project phase 5 (CMIP5, Meehl and Bony, 2012). The historical simulation has been performed forcing the CMIP5 models with observed concentration of greenhouse gasses, aerosols, ozone and solar irradiance, starting from an arbitrary point of a quasi-equilibrium control run. The RCPs scenarios follow a rising radiative forcing pathway leading to 8.5 W/m^2 and 4.5 W/m^2 in 2100, for the RCP8.5 and RCP4.5 respectively.

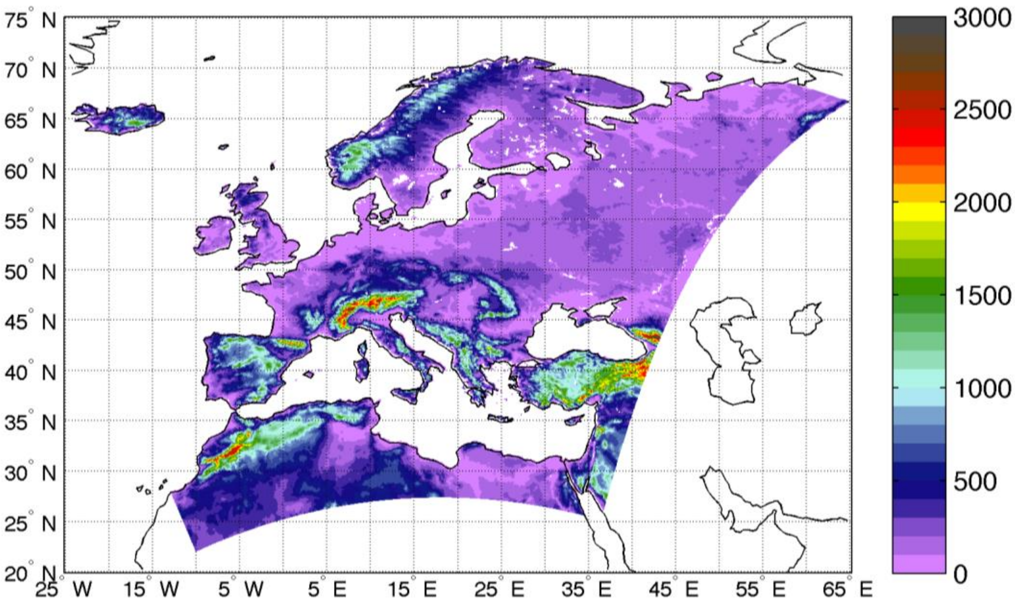

Figure 1 The EURO-CORDEX EUR-11 domain. The picture shows the representation of the orography. Units are [m].

3 Comparison between High and Low Horizontal Resolution

As already mentioned the first idea was to use CORDEX RCMs output to provide data for ICARUS targeted dynamical downscaling. After a first evaluation comparing RCM results to observations over the historical period we found that GCMs have a better performance at least in terms of surface temperature representation. Obviously this is not the case for precipitation, but since within ICARUS we are planning to downscale through a RCM at about 25 km resolution up to few kilometres, over the targeted areas, the improvement in precipitation representation can be left to the RCM itself. Figures 2 shows the differences in 2 meter temperature model bias, compared to the JRA-55 reanalysis (kobayashi et al., 2015), as represented by one of the RCM-GCM setup, object of this analysis: it emerges that the bias is more pronounced in the higher resolution data set (the RCM represented in the lower panel) compared to what is obtained by the lower resolution GCM.

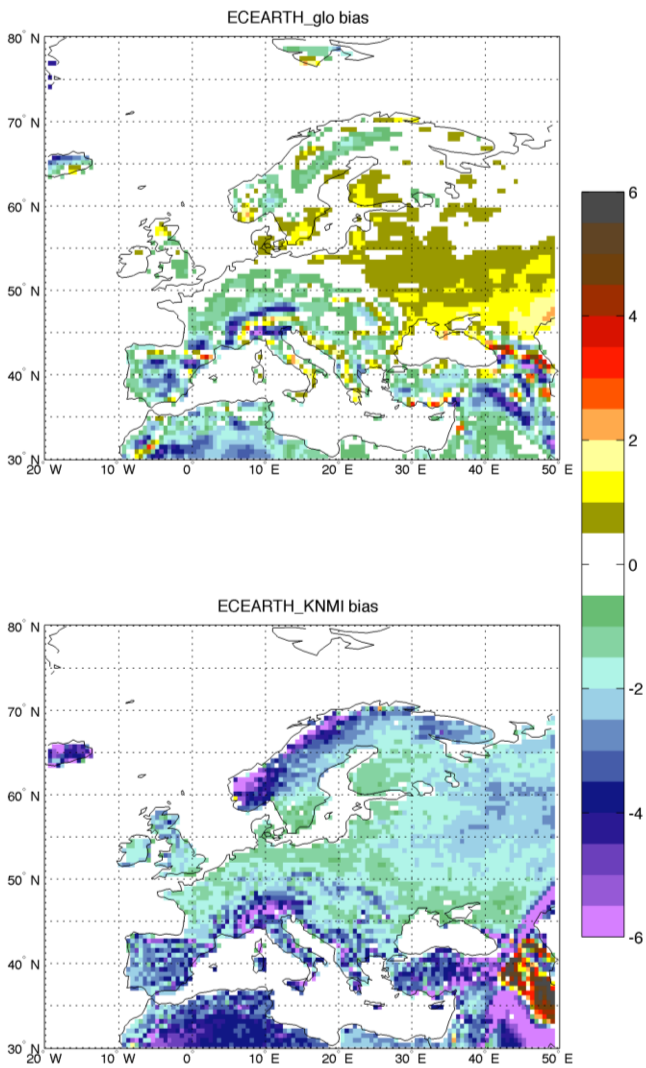

Figure 2: 2-meter averaged temperature bias (compared to JRA-55 reanalysis) in the RCM (lower panel) and the relative GCM used as boundary condition (upper panel) over the period 1976-2005.

Despite the small improvement in representing the right tail of the temperature distribution (p99-p90 metric - Scoccimarro et al. 2013, 2014 based on daily data) in the RCM compared to the GCM results (see figure 3), we decided to maintain the advantages of the higher temporal resolution (up to 6h) of the GCM CMIP5 results and their better performances in terms of averages, for ICARUS downscaling purposes.

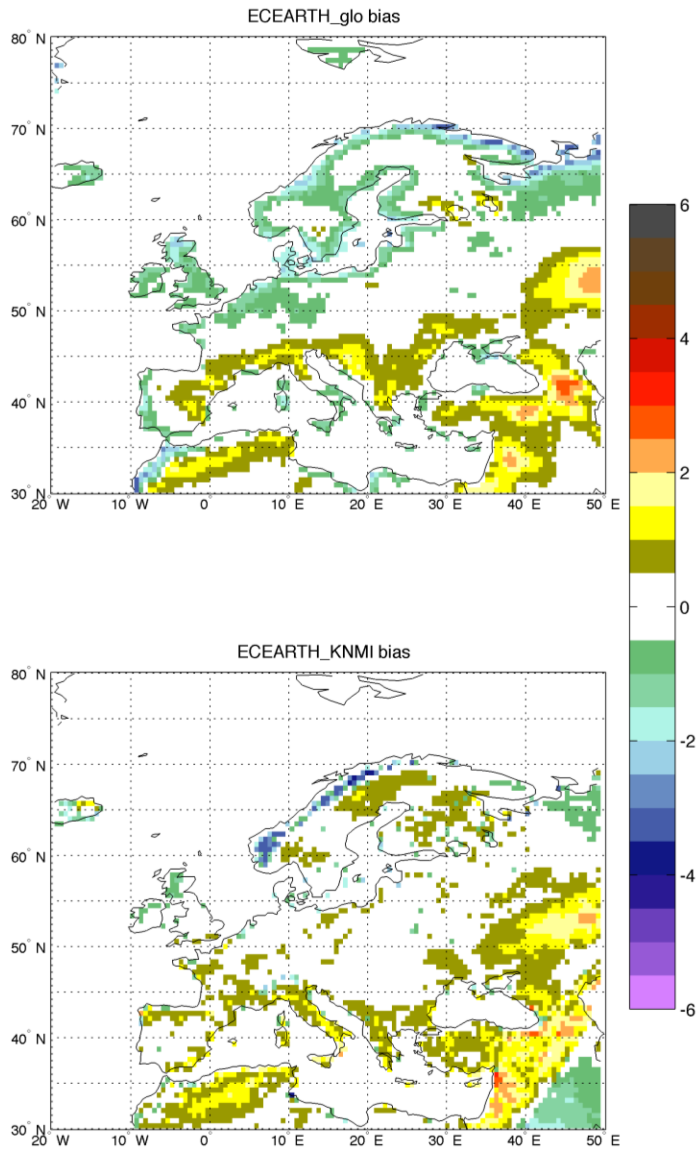

Figure 3: same as figure 2 but for the p99-p90 metric.

4 Data availability

Two different data set are then available for ICARUS partners:

- Two dimensional High resolution data from CORDEX (about 10 km resolution) at the daily time scale (listed in table 2) under RCP4.5 and RCP8.5 scenarios from 2006 to 2065.

- Three dimensional Boundary conditions from GFDL-CM3 GCM for downscaling purposes at the 6 hourly time scale (listed in table 3) under RCP8.5 scenario from 2006 to 2065.

As already mentioned due to the computational cost of the planned downscaling, in order to have a sufficiently long period representing the different future time slices, only one realization from one future scenario (RCP85) is provided as boundary condition from the GFDL-CM3 fully coupled GCM. GFDL-CM3 data have been subsampled in space over the domain indicated in figure 4.

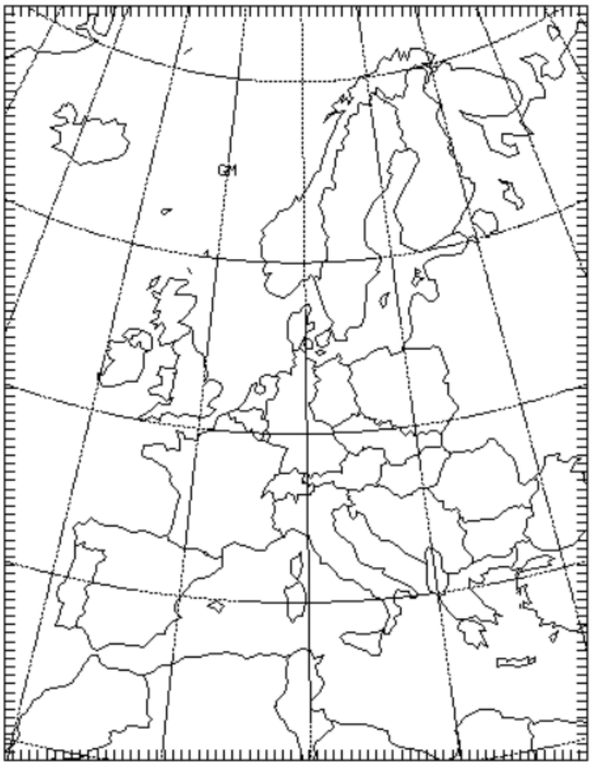

Figure 4: Domain defined for the ICARUS dynamical downscaling.

The period covered by the dataset is 2006-2065 (60 years) following two future scenarios (RCP45 and RCP85). The total amount of provided years is 480 (4 models X 2 scenarios X 60 years) for the CORDEX output at the daily time frequency and 60 years (1 model X 1 scenarios X 60 years) for the GFDL-CM3 model output at the 6 hourly time frequency, but the surface temperature (provided at the daily frequency). Some of the 6 hourly GCM data are obtained subsampling available 3 hourly data from the ESGF CMIP5 data set.

Table 2: List of meteorological fields provided at the 10 km spatial resolution, as resulting from the EURO-CORDEX Regional models listed in table 1.

Field Description	**Field Acronym**	**Vertical level**	**frequency**	**Field Unit**
Precipitation	pr	Surface	Daily	$[Kgm^{-2}s^{-1}]$
Surface relative humidity	hurs	surface	daily	[%]
Surface solar radiation	rsds	surface	daily	[W/m2]
Wind module	sfcWind	10 meter	daily	[m/s]
Wind module max	sfcWindmax	10 meter	daily	[Pa]
zonal wind speed	uas	10 meter	daily	[m/s]
meridional wind speed	vas	10 meter	daily	[m/s]
2 meter Temperature	tas	2 meter	daily	[K]
2 meter Air Temperature max	tasmax	2 meter	daily	[K]
2 meter Air Temperature min	tasmin	2 meter	daily	[K]

Table 3: List of meteorological fields provided from the GCM model as boundary conditions for downscaling.

Field Description	**Field Acronym**	**model levels**	**frequency**	**Field Unit**
Specific humidity on model levels	hus	surface	6h	[kg/kg]
Surface specific humidity	huss	surface	6h	[kg/kg]
Surface pressure	ps	Surface	6h	[Pa]
Sea level Pressure	psl	Surface	6h	[Pa]
10 meter zonal wind speed	uas	10 meter	6h	[m/s]
10 meter meridional wind speed	vas	10 meter	6h	[m/s]
Zonal wind speed on model levels	ua	48	6h	[m/s]
Meridional speed on model levels	va	48	6h	[m/s]
2 meter Temperature	tas	2 meter	6h	[K]
Air Temperature on model levels	ta	48	6h	[K]
Surface Temperature	ts	Surface	daily	[K]

A reference person, within the ICARUS project, is in contact with CMCC to define specific requirements and delivery methodology.

The data format used is NetCDF (http://www.unidata.ucar.edu/software/netcdf/). 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.

Any additional data elaboration leading to extreme events computation of the proposed parameters in table 2, can be required following the sheet template available for ICARUS partners (Excel sheet, summarized in figure 5). In particular the case study users are supposed to provide the spatial boundaries of the domain, together with few additional information about the data format (netCDF or ASCII) and data kind of information (gridded data or data averaged over the domain) they are interested in. All of the required shell scripts are available at CMCC and ready to match user requirements for the computation of the following extreme indexes:

-extreme precip (99 percentile) [mm/d]
-intense precip (95 percentile) [mm/d]
-R95N * [d] -> number of days with daily precipitation exceeding the long term 95th percentile
-RL5N ** [d] -> number of days with daily precipitation below the 5th long term percentile
-extr. high temp (99 percentile) [K]
-extr. high max temp (99 percentile) [K]
-extr low temp (1 percentile) [K]
-extr low min temp (1 percentile) [K]
-high temp (95 percentile) [K]
-high max temp (95 percentile) [K]
-low temp (5 percentile) [K]
-low min temp (5 percentile) [K]
-HWDI **** [d] -> number of days where, in intervals of at least 6 consecutive days, Tmax > Tmax_**long_term** + 5 degC.
-extreme wind (99 percentile) [m/s]
-extreme max wind (99 percentile) [m/s]

Despite few cases, data are made available through the CMCC ftp server (download.cmcc.bo.it – user and passwd sent privately to the ICARUS partners reference person).

CLIMATE DATA INFO-SHEET template

This document helps to identify climate parameters and spatial domain necessary for each ICARUS case study.

All of the required data will cover the period 1976 to 2065.

From 2006 to 2065 two series of data will be provided, following the RCP4.5 and RCP8.5 scenarios.

Case study name: ?

Responsible person: ?

Number of climate models to consider: ? *please insert a number <=4 (the maximum number of climate models available is 4)*

Type of data format ? please insert "ascii" (text) or "netCDF" (common climate binary format)

Spatial domain corners:	lat1 lon1	lat1 lon2	lat2 lon1	lat2 lon2
	? ?	? ?	? ?	? ?

CL. DERIVED PARAMETERS (annual values) *please insert a "G" if you are asking to compute these indexes over all the grid cells within your case study domain, or "A" if you need the spatial average over the entire domain*

extreme precip (99 percentile) [mm/d]	?	based on daily precipitation
intense precip (95 percentile) [mm/d]	?	based on daily precipitation
R95N * [d]	?	based on daily precipitation
RL5N ** [d]	?	based on daily precipitation
CDD * [d]**	?	based on daily precipitation
extr. high temp (99 percentile) [K]	?	based on daily temperature
extr. high max temp (99 percentile) [K]	?	based on maximum daily temperature
extr low temp (1 percentile) [K]	?	based on daily temperature
extr low min temp (1 percentile) [K]	?	based on minimum daily temperature
high temp (95 percentile) [K]	?	based on daily temperature
high max temp (95 percentile) [K]	?	based on maximum daily temperature
low temp (5 percentile) [K]	?	based on daily temperature
low min temp (5 percentile) [K]	?	based on minimum daily temperature
HWDI ** [d]**	?	based on maximum daily temperature
extreme wind (99 percentile) [m/s]	?	based on daily 10m wind
extreme max wind (99 percentile) [m/s]	?	based on daily max 10m wind

* R95N	Number of days with daily precipitation exceeding the **long term** (1976-2005) 95th percentile
** RL5N	Number of days with daily precipitation lower than the **long term** 5th percentile
*** CDD	Maximum (not total) number of consecutive dry days (dry day defined if precipitation is < 1 [mm/day])
**** HWDI	number of days where, in intervals of at least 6 consecutive days, TX > Tx**long_term** + 5 degC.

Figure 5: Climate info sheet available for extreme events computation requests by ICARUS partners.

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