“Implementation of a forecAsting System for urban heaT Island effect for the development of urban adaptation strategies” (LIFE ASTI)

Action C.1 **Methodological Report on UHI Forecasting Systems**

Thessaloniki July 2019

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I Methodological Report on UHI Forecasting Systems

This document addresses the Set-up of the pilot operational UHI forecasting systems (action C.1), including the technical details realized in the systems, with an overview of the methodologies and in accordance to the Preliminary Design Report (PDR) and the Architectural and Functional Report (AFR).

LIFE ASTI, as a LIFE funded project maintains an effective and uncomplicated management. The beneficiaries integrate the respective tasks and communication with prompt processes. All procedures are simple and direct on a reasonable level.

The focus of the Methodological Report on UHI Forecasting Systems is the description of the technical details, the datasets, the UHI-related products and the methods and tools utilized in the LIFE-ASTI platform.

i. Set-up of the pilot operational UHI forecasting systems

a. WRF-SLUCM modeling system Set-up

The modeling system coverage follows that of the PDR, aiming on easy transferability and replicability of the systems elsewhere. The latest version of the WRF model (4.1) replaced the current one (3.9.1.1), in order to include several updated schemes that can facilitate the performance of the modeling system. The five nested domains (Fig. 1) have spatial resolutions of 18 km (d01), 6 km (d02) and 2 km (d03, d04, d05). The first domain (d01; mesh size of 460x270) cover most of the Europe, the North Africa and the Middle East to simulate the synoptic meteorological conditions. The second domain (d02; mesh size of 450x345) includes the eastern Mediterranean, while two innermost domains focus on the studied urban areas of Thessaloniki, Greece, (d03; mesh size of 75x75) and Rome, Italy, (d05; mesh size of 78x45). All modeling domains have the same vertical structure composing of 35 unevenly spaced full sigma layers from the lowest layer near the surface (~ 30 m) to the model top, defined at 100 hPa.

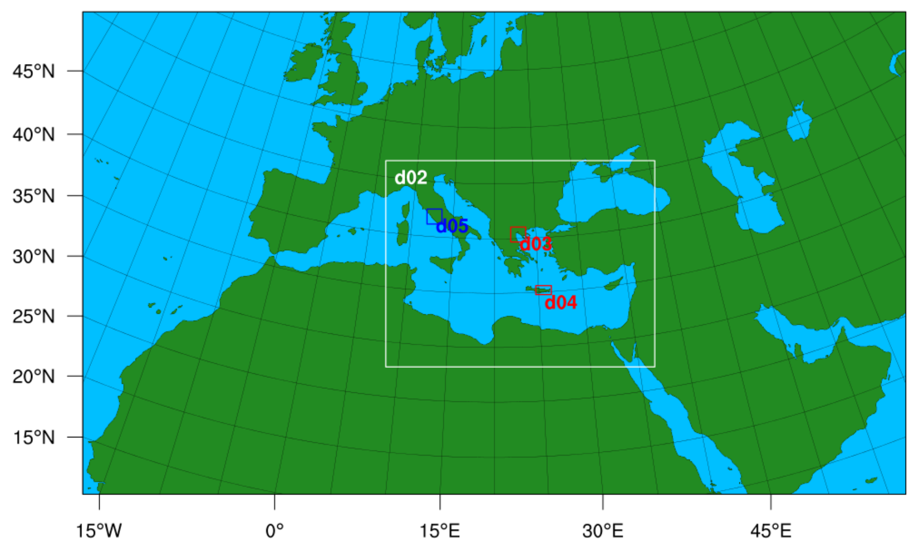


Figure 1. Configuration of the five (2-way) nested WRF modeling domains

The meteorological fields needed to feed the coarse (d01) domain are taken from the Global Forecast System (GFS; http://www.emc.ncep.noaa.gov/GFS/doc.php) of National Centers for Environmental Prediction (NCEP). The 00:00 UTC forecast in 3h temporal resolution are used to provide the various surface and upper-level atmospheric and land-soil variables at horizontal grid resolutions of 0.25°.

On the input data a major upgrade was made for the Sea Surface Temperature (SST). The NCEP SST product is utilized (https://polar.ncep.noaa.gov/), additionally to the other fields, with a horizontal resolution of 0.0833°. The 00:00 UTC forecast of the previous day is used during the simulation of LIFE-ASTI modeling system.

The physics options are summarized in Table 1. The only difference relative to the PDR is the planetary boundary layer parameterization, which was switched from ACM2 (Pleim et al. 2007a, 2007 b) to Yosei University scheme (Hong, Noh and Dudhia 2006). This change was made because ACM2 produces extreme turbulent momentum exchange coefficients, which might lead to intense mixing and unrealistically lower temperature with profound concequences in the UHI intensity.

Table 1. Summary of the WRF physics options

Physics	Parameterization	References
Microphysics (clouds)	WRF single-moment 5-class (WSM5)	Hong et al. (2004)
Cumulus (convection)*	Kain-Fritsch (KF)	Kain (2004)
Planetary boundary layer	Yosei University scheme (YSU)	Hong et al. (2006)
Surface layer	Revised MM5	Jiménez et al. (2012)
Land surface	Noah model	Tewari et al. (2004)
Short-wave radiation	Dudhia	Dudhia (1989)
Long-wave radiation	rapid radiative transfer model for global circulation model (GCM) applications (RRTMG)	Iacono et al. (2008)

* Cumulus parameterization will be used only for domains d01 and d02

Two major changes on the set-up were made in the frame of Action C.1: i) the approach the landuse/landcover datasets utilized and ii) the horizontal resolution of the topographic data.

1. Concerning the land use, the preliminary design included the utilization of the MODIS/IGBP 20-class land use dataset in the domains of Europe (d01) and southeastern Mediterranean (d02). For the urban-scale domains of Thessaloniki (d03) and Rome (d04) the CORINE 2012 land use categories, reclassified to MODIS/IGBP 20 classes, were designed initially for use within WRF. The latter approach for Rome and Thessaloniki has the disadvantage of aggregating several urban areas, losing the spatial heterogeneity of the urban fabric. Instead of this, it has been chosen to utilize all 44 classes in the modeling system, assigning the surface properties based on the correspondence of CORINE and USGS land use classes and their recommended properties, as described in Pineda et al. (2004). This approach enables us to refine/update several surface properties and improve the system's performance in the future. It will also facilitate the investigation of the impact of the green interventions in the framework of Actions C.5 and C.7 through the explicit definition of CORINE's class "Green Urban Areas". The CORINE dataset is retrieved from the European Environmental Agency (EEA) in the framework of the "coordination of information on the environment (CORINE)" project in raster (GeoTIFF) format (https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012?tab=download.)

Additionally, the MODIS/IGBP dataset described in PDR, has been replaced for d01 and d02 with the Global Land Cover by National Mapping Organizations (GLCNMO) version 1 (Tateishi et al. (2014)). The GLCNMO v1 includes also 20 classes with 1km horizontal resolution, as with MODIS/IGBP, but with newer source data. The main difference and the reason of this choice is the classification followed in this dataset, which provides two separate categories for bare surfaces, like deserts. Bearing in mind the fact that the heat wave originate from such surfaces in North Africa, their appropriate representation is expected to improve the properties of the hot air masses and concequently their indirect impact at the UHI. The data are available at https://globalmaps.github.io/glcnmo.html.

2. Concerning the topography, the Shuttle Radar Topography Mission (SRTM) dataset (Farr et al., 2007), as proposed in A.1 deliverable, but at 90 m resolution applied across all domains. This choice was made to keep the consistency across the domains and the spatial scale of the forecoming final version of the CORINE 2018 dataset in the mid-2019, which will be 100m and will replace the previous version.

All datasets have been preprocessed with the QGIS v3.4.9 (https://qgis.org/en/site/). CORINE is reprojected from LAEA (EPSG:3035) to WGS84 (lat-lon), which is the compatible projection for WRF input datasets. SRTM and GLCNMO are already in WGS84. Then each dataset is split in tiles, for easier manipulation. Utilizing the Geospatial Data Abstraction Library (GDAL) and shell scripting on the Linux machines of AUTh every tile is converted to ASCII file. With the aid of the "write_geogrid.c" in WRF's code and of a custom Fortran code from the model's forum the datasets have been converted to the WRF-compatible binary interleaved files. Further information can been found at http://forum.wrfforum.com/viewtopic.php?f=22&t=2266. Attention has been paid for for CORINE's invalid values (i.e. 255). Such invalid data in our domains exist over the ocean. Thus, these values are replaced in the Fortran code with the category 44. The land use categories and the SRTM topography, as utilized in WRF model, are presented in Figures 2-6 a,b.

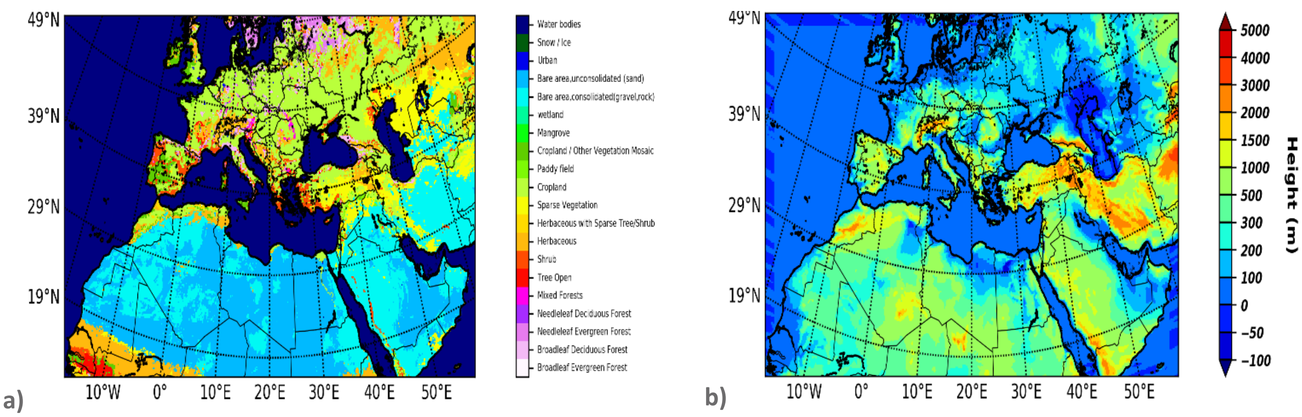


Figure 2. (a) GLCNMO Land use and (b) SRTM4 topography of the WRF modeling domain D01.

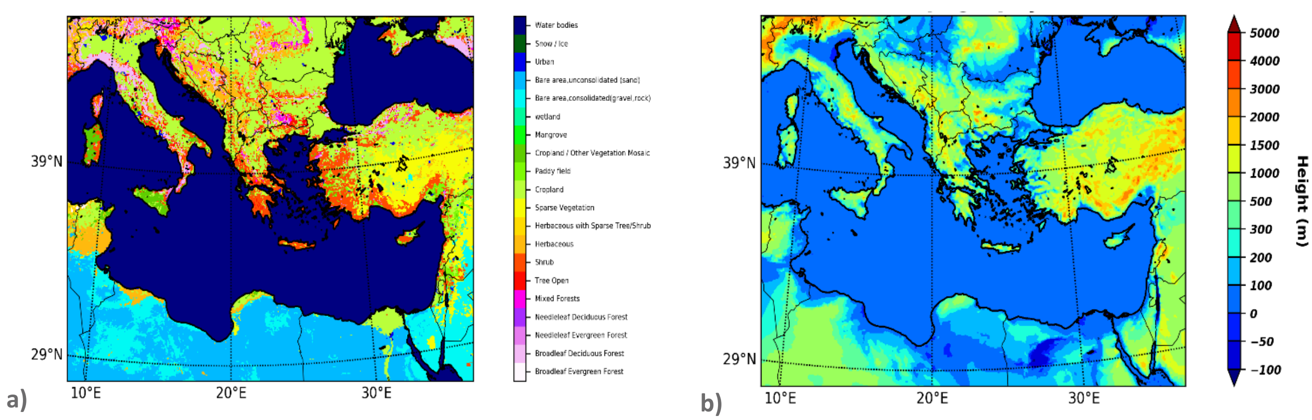


Figure 3. (a) GLCNMO Land use and (b) SRTM4 topography of the WRF modeling domain D02.

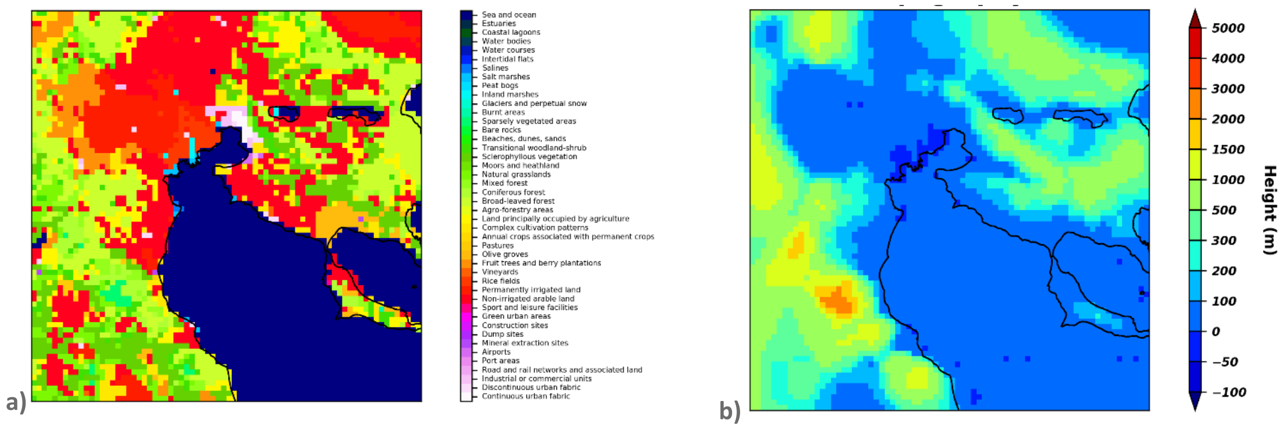


Figure 4. (a) GLCNMO Land use and (b) SRTM4 topography of the WRF modeling domain D03.

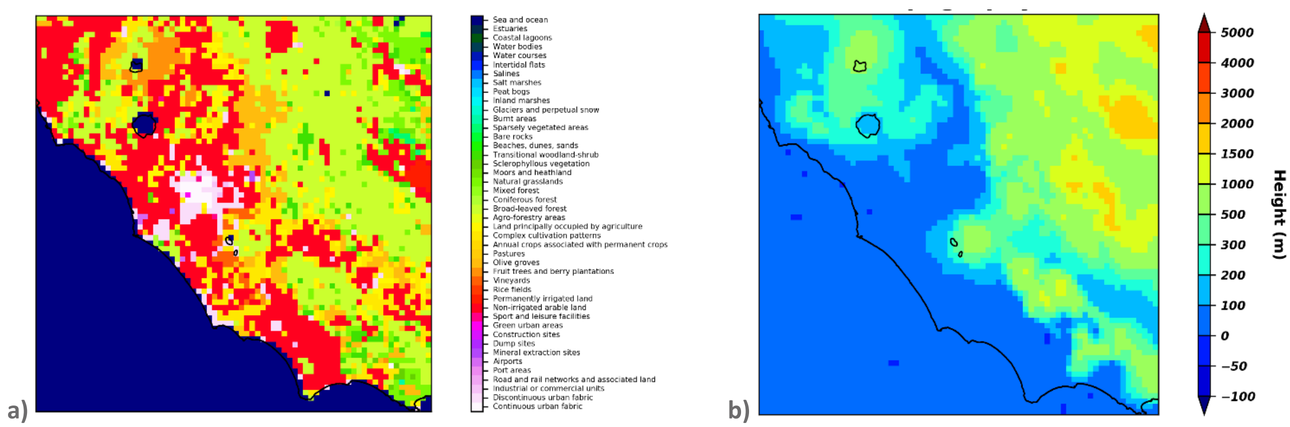


Figure 5. (a) GLCNMO Land use and (b) SRTM4 topography of the WRF modeling domain D04.

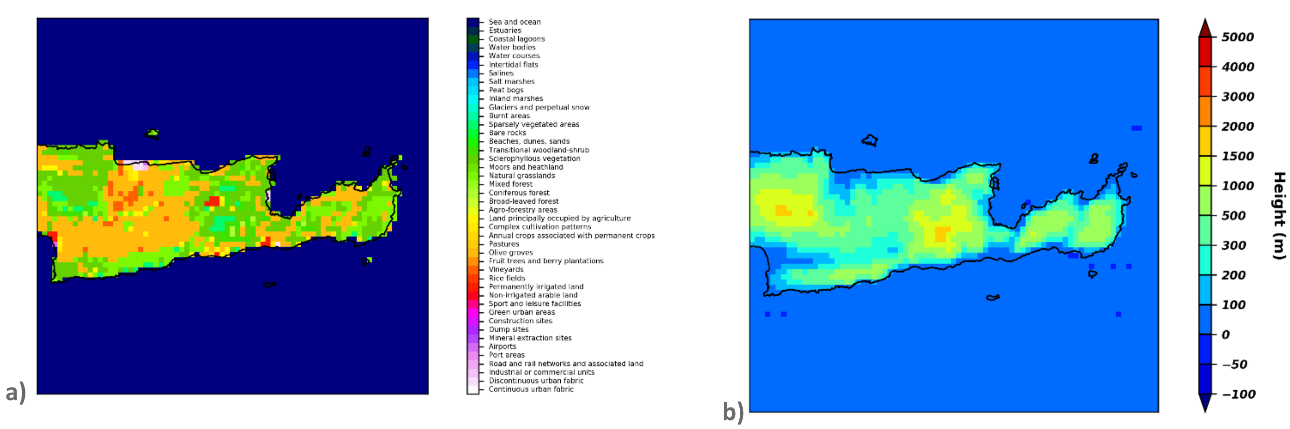


Figure 6. (a) GLCNMO Land use and (b) SRTM4 topography of the WRF modeling domain D05.

The implementation of the Single-Layer Urban Canopy Model (SLUCM) requires several properties for the description of the urban environment for three distinct categories: a) High-Intensity Residential (HIC), b) Low-Intensity Residential (LIC) and c) Industrial-Commercial (IC). Since the land use databases have change to GLCNMO and CORINE, the appropriate assignment of certain land use categories as HIC, LIC and IC must be done. GLCNMO contains only one urban category (#18), which is associated with residential areas in our domains. Thus, this land use category is assigned as HIR. The LIR and IC don't correspond to any GLCNMO land use and are kept null. On the other hand, CORINE contains three categories, namely Continuous Urban Fabric (#1), Discontinuous Urban Fabric (#2) and Industrial or Commercial units (#3), which are assigned to HIR, LIR and IC. Based on the above and following the PDR and Giannaros et al. (2018), the land surface properties (i.e. emissivity and albedo) and urban canopy features (building height, urban canopy fraction etc.) are assigned.

b. WRF-SLUCM operation and Pilot Operational Simulations Database (POSD)

The WRF-SLUCM modeling system is running since 30th of June 2019 at the Linux systems of AUTh , with a series of shell scripts developed from AUTh team for the automated download of the initial/boundary conditions and its daily operation. Every day the operating system start running at 7 a.m. greek local time (5 a.m. UTC), with the simulated forecast starting time at 00:00 UTC of the same day. The operation of WRF consists of two steps: 1) downloading of GFS and SST data and 2) running the WRF-SLUCM. The spin-up period was selected to be 1 day, ensuring the elimination of potential errors from the initial conditions. Thus, the next 3 forecasted days are considered as valid for the post-processing. Each simulation of the WRF-SLUCM for all domains lasts 11 hours, running on 2 Intel Xeon Gold 6152 and producing all the necessary parameters for the downscaling and the derivation of the UHI-related products.

The ouput consists of 5 separate files, with the suffix wrfout_d<domain>_<simulation starting date> in netcdf format, one for each domain. The occupied space is 12Gb, 14Gb, 557Mb, 479Mb and 542Mb for the domains d01, d02, d03, d04 and d05 respectively. All files are saved on the Pilot Operational Simulations Database (POSD), in a linux machine of 30T space, dedicated for this purpose. The output in POSD is archived under the directories OPERATIONAL/WRF_OUT/YYYYMMDD, structured on a daily basis. Here, the "YYYYMMDD" naming is the simulation starting date, with YYYY the 4-digit year, MM the 2-digit month and DD the 2-digit day number. POSD can be read-only accessible through ftp for authorized users, after communicating with the AUTh team.

c. Downscaling method

The present project aims to map the horizontal distribution of the Urban Heat Island effect in high resolution. This requires the application of the modeling system in high horizontal grid resolution; in principle lower than 1 km. However, this is not possible, due to limitations in the availability of computational resources and due to numerical problems. In order to address this issue, statistical downscaling can be applied as an alternative method for producing high-resolution forecasts without increasing computer resource requirements (Giannaros T.M. et al, 2014). In this case, the local climate is predicted through statistical relationships that combine the model forecasts with fine-scale historical observations and various parameters that govern the variability of the meteorological fields (e.g., land use and topography). However, the available data from the existing monitoring network are scarce and can't be used for the development of the envisaged downscaling techniques. For the purposes of the present project, a number of new stations will be installed both in Rome and in Thessaloniki. Thus, a simplified approach is followed in the current phase while this will be updated to a detailed downscaling method when the installation of the new monitoring network is completed and there are available data for at least six months of operation.

- The temporary downscaling method, currently implemented in the forecasting system, focuses on temperature and relative humidity at 2m at a 250m horizontal resolution. It is based on the results of the WRF-SLUCM with small corrections due to ground elevation and CORINE land uses.
- The temperature at 2m is initially corrected based on the dry adiabatic lapse rate (6^{o}C/km) and the difference between SRTM and WRF-SLUCM groud elevation.
- The temperature at 2m is then corrected based on CORINE land uses.

- Utilizing the corrected temperature at 2m from the previous steps and the vapor mixing ratio from WRF-SLUCM, the relative humidity at 2m is calculated for the 250 m resolution grid.

d. Post-Proccessing Tools (PPT), UHI products and Post-Processing Database (PPD)

When the WRF-SLUCM simulation of the day is finished, the Post-Processing Tools (PPT) are running at the Linux machines of AUTh. The PPT is an automated script in shell, which in turn calls a Python script with an interface with GDAL to perform the downscale, calculate the UHI-related parameters, reproject to WGS84 and export the data in Tagged Image File Format (.tiff). The Python script operates in an iterative way for each output parameter, making the post processing flexibile on future updates/changes. The PPT is applied only on the 3 valid forecasting dates of WRF-SLUCM, bypassing the 1 spin-up day.

Before the downscale, CORINE and SRTM datasets have been preprocessed with the aid of the Climate Data Operators (CDO, https://code.mpimet.mpg.de/projects/cdo/embedded/cdo.pdf) and the programming language Python (https://www.python.org/). The dataset of CORINE, is reprojected with the CDO and Python from EPSG:3035 to WRF-SLUCM Lambert Conformal Conic projection at 250m horizontal resolution with the nearest neighbor interpolation method and the output is saved in netcdf format. A similar approach is followed for SRTM, with the first-order conservative method as an interpolation option (remapcony in CDO), appropriate for continuous fields. This process is done only once for d03, d04 and d05 (Thessaloniki, Rome and Herakleion).

Once the land use and topography data from CORINE and SRTM are ready at 250m, the PPT performs the downscale described in the previous section, and then it calculates the required UHI-related fields, as defined in the PDR. Additionally, the Total Cloud Cover Fraction has been added, since it is need for the operation of the Heat Health Warning System. The output is provided in WGS84 projection, for better visualization in the LIFE-ASTI platform.

The ouput consists of 13 compressed (zipped) files for each area of interest (Thessaloniki, Rome, Herakleion), one for every output parameter, with the suffix {city}{param}_YYYYMMMDDTHHmmZ.zip. The date of the zipped file is the simulation starting date of the WRF-SLUCM, with YYYY the 4-digit year, MM the 2-digit month, DD the 2-digit day number, HH the 2-digit hour and mm the 2-digit minutes in UTC. The total occupied space of the resultant 39 files is ~680Mb. Each one, when unzipped, contains the parameter's hourly data in .tiff format, with a similar naming ({city}{param}_YYYYMMMDDTHHmmZ.tiff). Here, the "YMMMDDTHHmmZ" part is the actual valid forecasting date and hour in UTC.

All PPT output files are saved on the Post-Processing Database (PPD), in a linux machine of 40T space, dedicated for this purpose. The output in PPD is archived under the directories LIFE-ASTI_OUT/Tiff_files/YYYYMMDD, structured on a daily basis. Here, the "YYYYMMDD" naming is the simulation starting date, with YYYY the 4-digit year, MM the 2-digit month and DD the 2-digit day number. PPD can be read-only accessible through ftp for authorized users, after communicating with the AUTh team.

ii. Development of the LIFE ASTI system platform (LASP)

a. Set-up of the online LIFE-ASTI platform (LASP)

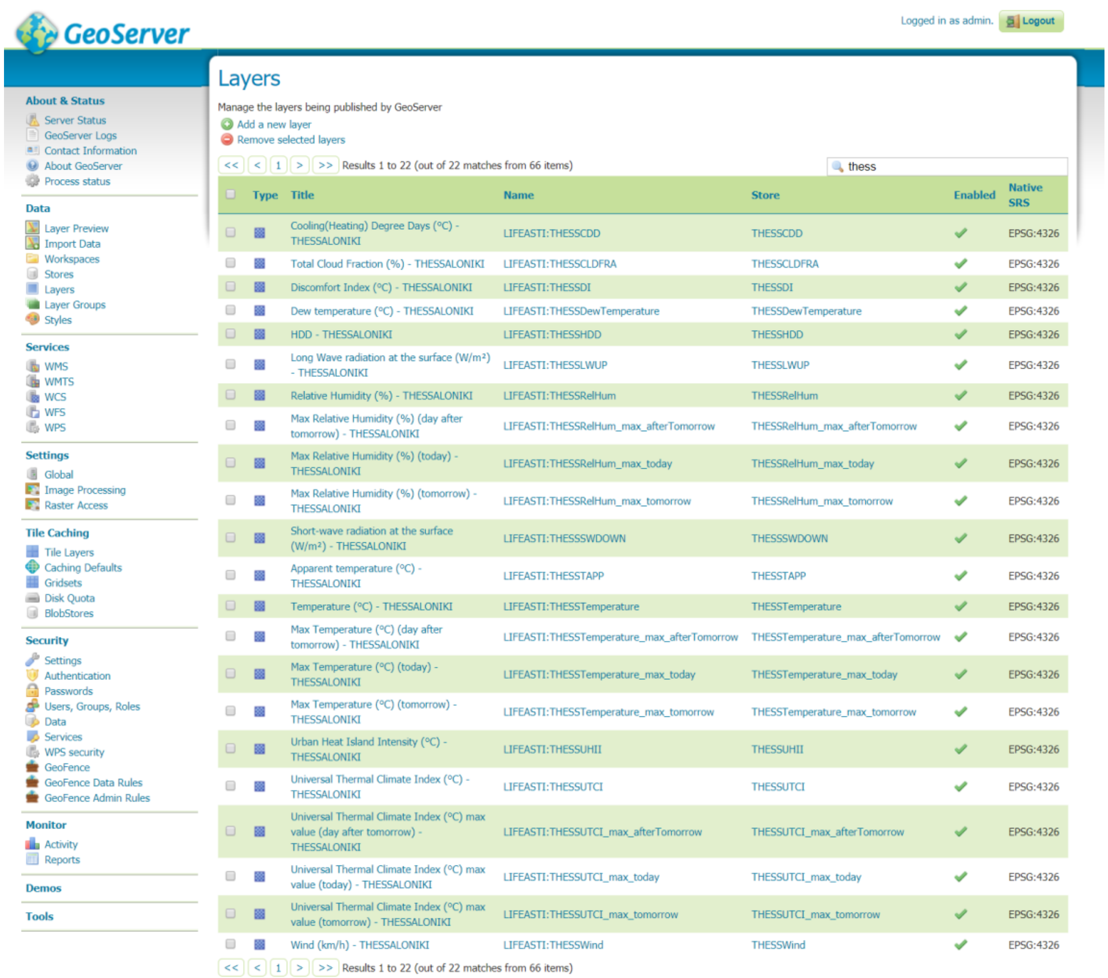
The LIFE ASTI platform was setup using the following system components:

- Database

  The **POSTGRESQL** RDBMS was installed and used. The database stores information about meteorological stations, forecast data layers, as well as the model results.

- For each forecast layer the database stores information about the time attribute domain (image mosaic process performed by the Web GIS Server).
- Model statistics which are produced from the transformation services are also stored in the database, at point locations (meteorological stations) and aggregated over the city districts.

- Web GIS Server
  GEOSERVER was installed and used. Since model data are time enabled raster layers, the image mosaic plugin was used to expose the data using the OGC WMS, WFS and WCS services. Figure 7 presents the Geoserver Layers which have been setup to access the forecast data for Thessaloniki.



Type	Title	Name	Store	Enabled	Native SRS
	Cooling(Heating) Degree Days (°C) - THESSALONIKI	LIFEASTI:THESSCDD	THESSCDD	✓	EPSG:4326
	Total Cloud Fraction (%) - THESSALONIKI	LIFEASTI:THESSCLDFRA	THESSCLDFRA	✓	EPSG:4326
	Discomfort Index (°C) - THESSALONIKI	LIFEASTI:THESSDI	THESSDI	✓	EPSG:4326
	Dew temperature (°C) - THESSALONIKI	LIFEASTI:THESSDewTemperature	THESSDewTemperature	✓	EPSG:4326
	HDD - THESSALONIKI	LIFEASTI:THESSHDD	THESSHDD	✓	EPSG:4326
	Long Wave radiation at the surface (W/m²) - THESSALONIKI	LIFEASTI:THESSLWUP	THESSLWUP	✓	EPSG:4326
	Relative Humidity (%) - THESSALONIKI	LIFEASTI:THESSRelHum	THESSRelHum	✓	EPSG:4326
	Max Relative Humidity (%) (day after tomorrow) - THESSALONIKI	LIFEASTI:THESSRelHum_max_afterTomorrow	THESSRelHum_max_afterTomorrow	✓	EPSG:4326
	Max Relative Humidity (%) (today) - THESSALONIKI	LIFEASTI:THESSRelHum_max_today	THESSRelHum_max_today	✓	EPSG:4326
	Max Relative Humidity (%) (tomorrow) - THESSALONIKI	LIFEASTI:THESSRelHum_max_tomorrow	THESSRelHum_max_tomorrow	✓	EPSG:4326
	Short-wave radiation at the surface (W/m²) - THESSALONIKI	LIFEASTI:THESSSWDOWN	THESSSWDOWN	✓	EPSG:4326
	Apparent temperature (°C) - THESSALONIKI	LIFEASTI:THESSTAPP	THESSTAPP	✓	EPSG:4326
	Temperature (°C) - THESSALONIKI	LIFEASTI:THESSTemperature	THESSTemperature	✓	EPSG:4326
	Max Temperature (°C) (day after tomorrow) - THESSALONIKI	LIFEASTI:THESSTemperature_max_afterTomorrow	THESSTemperature_max_afterTomorrow	✓	EPSG:4326
	Max Temperature (°C) (today) - THESSALONIKI	LIFEASTI:THESSTemperature_max_today	THESSTemperature_max_today	✓	EPSG:4326
	Max Temperature (°C) (tomorrow) - THESSALONIKI	LIFEASTI:THESSTemperature_max_tomorrow	THESSTemperature_max_tomorrow	✓	EPSG:4326
	Urban Heat Island Intensity (°C) - THESSALONIKI	LIFEASTI:THESSUHII	THESSUHII	✓	EPSG:4326
	Universal Thermal Climate Index (°C) - THESSALONIKI	LIFEASTI:THESSUTCI	THESSUTCI	✓	EPSG:4326
	Universal Thermal Climate Index (°C) max value (day after tomorrow) - THESSALONIKI	LIFEASTI:THESSUTCI_max_afterTomorrow	THESSUTCI_max_afterTomorrow	✓	EPSG:4326
	Universal Thermal Climate Index (°C) max value (today) - THESSALONIKI	LIFEASTI:THESSUTCI_max_today	THESSUTCI_max_today	✓	EPSG:4326
	Universal Thermal Climate Index (°C) max value (tomorrow) - THESSALONIKI	LIFEASTI:THESSUTCI_max_tomorrow	THESSUTCI_max_tomorrow	✓	EPSG:4326
	Wind (km/h) - THESSALONIKI	LIFEASTI:THESSWind	THESSWind	✓	EPSG:4326

Results 1 to 22 (out of 22 matches from 66 items)

Figure 7: List of Layers for Thessaloniki in Geoserver

In addition, for each layer the symbology was defined using the Styled Layer Descriptor (SLD) markup language. The default symbology for the forecasting meteorological layers was ranges which presents data with different colors according to their value. As an example, the SLD for UTCI is presented below in Fig. 8.

```xml
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<StyledLayerDescriptor version="1.0.0"
  xsi:schemaLocation="http://www.opengis.net/sld StyledLayerDescriptor.xsd"
  xmlns="http://www.opengis.net/sld"
  xmlns:ogc="http://www.opengis.net/ogc"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
 <NamedLayer>
  <Name>Multi color gradient</Name>
  <UserStyle>
   <Title> Multi color gradient  for UTCI</Title>
   <FeatureTypeStyle>
    <Rule>
     <RasterSymbolizer>
      <ColorMap type="intervals">
          <ColorMapEntry color="#ffffff" quantity="-9999" opacity="0"/>
          <ColorMapEntry color="#000080" quantity="-40" label="Up to -40"/>
          <ColorMapEntry color="#0000C0" quantity="-27" label="From -40 to -27"/>
          <ColorMapEntry color="#0000FF" quantity="-13" label="From -27 to -13"/>
          <ColorMapEntry color="#0060FF" quantity="0" label="From -13 to 0"/>
          <ColorMapEntry color="#00C0FF" quantity="9" label="From 0 to 9"/>
          <ColorMapEntry color="#00C000" quantity="26" label="From 9 to 26"/>
          <ColorMapEntry color="#FF6600" quantity="32" label="From 26 to 32"/>
          <ColorMapEntry color="#FF3300" quantity="38" label="From 32 to 38"/>
          <ColorMapEntry color="#CC0000" quantity="46" label="From 38 to 46"/>
          <ColorMapEntry color="#800000" quantity="60" label="Over 46"/>
      </ColorMap>
     </RasterSymbolizer>
    </Rule>
   </FeatureTypeStyle>
  </UserStyle>
 </NamedLayer>
</StyledLayerDescriptor>
```

Figure 8: SLD and legend for UTCI**.** The Geoserver instance is available at: https://lifeasti.getmap.gr/geoserver/web/

- Metadata Server

  For metadata management the **GEONETWORK OPENSOURCE** software was installed and used. Geonetwork is a free and open source (FOSS) cataloging application for spatially referenced resources. It is a standardized and decentralized spatial information management system designed to enable access to geo-referenced databases, cartographic products and related metadata from a variety of sources, enhancing the spatial information exchange and sharing between organizations and their audience, using the internet. It supports the Z39.50 protocol as well as the OGC Web Catalog Service (CSW). The Geonetwork instance is available at: https://lifeasti.getmap.gr/geonetwork

Figure 9 presents the Geonetwork search page. At the top there is a free text search box where for example the user can select to search for “temperature” or “wind” etc. At the left there is the filter section where several filters can be applied in order to narrow the search results. The results are presented in the main section of the page as data tiles.

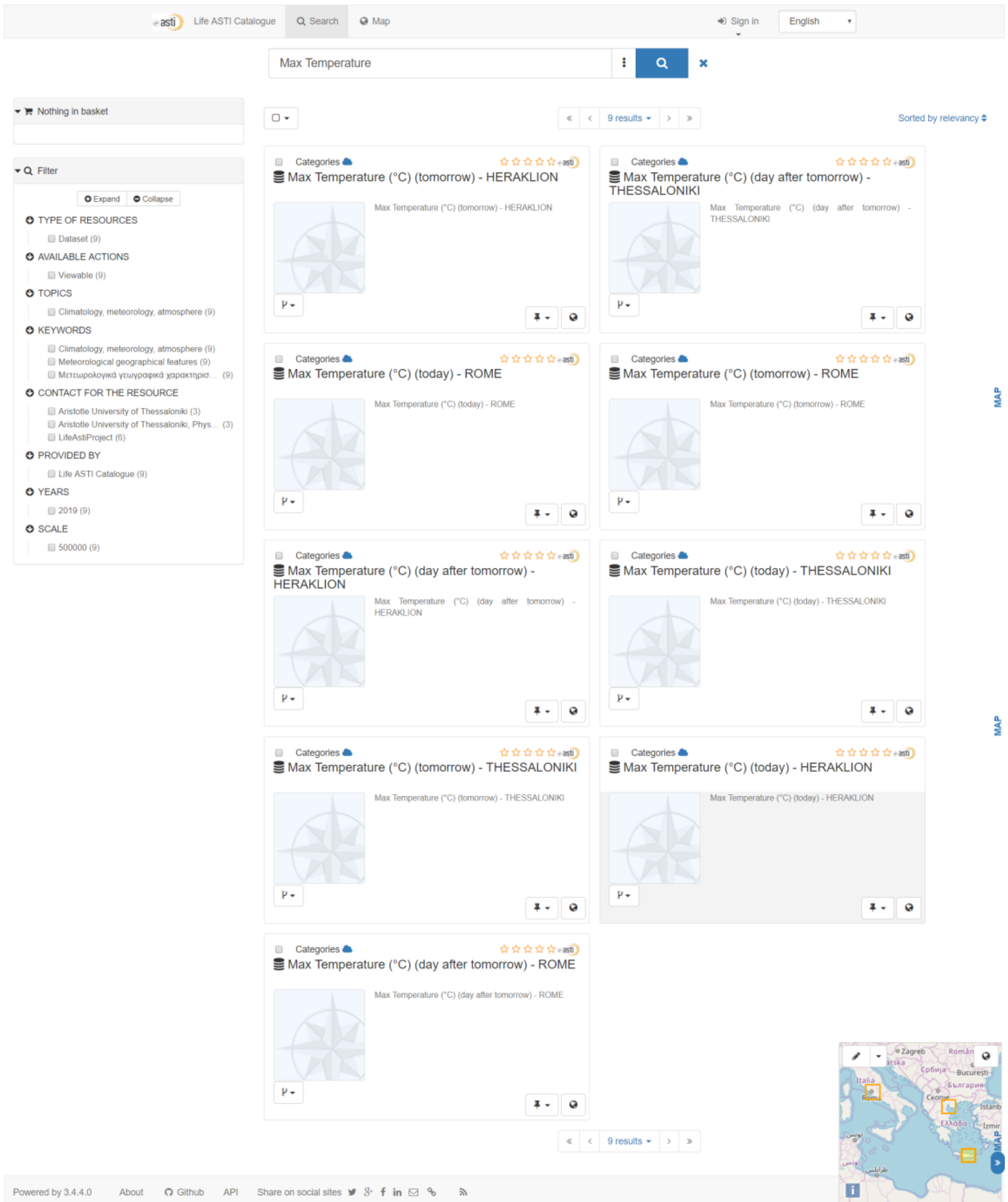


Figure 9: The Geonetwork Resources Search Page

For each result additional information is available which is presented when the user clicks at any of the resources (Figure 10).

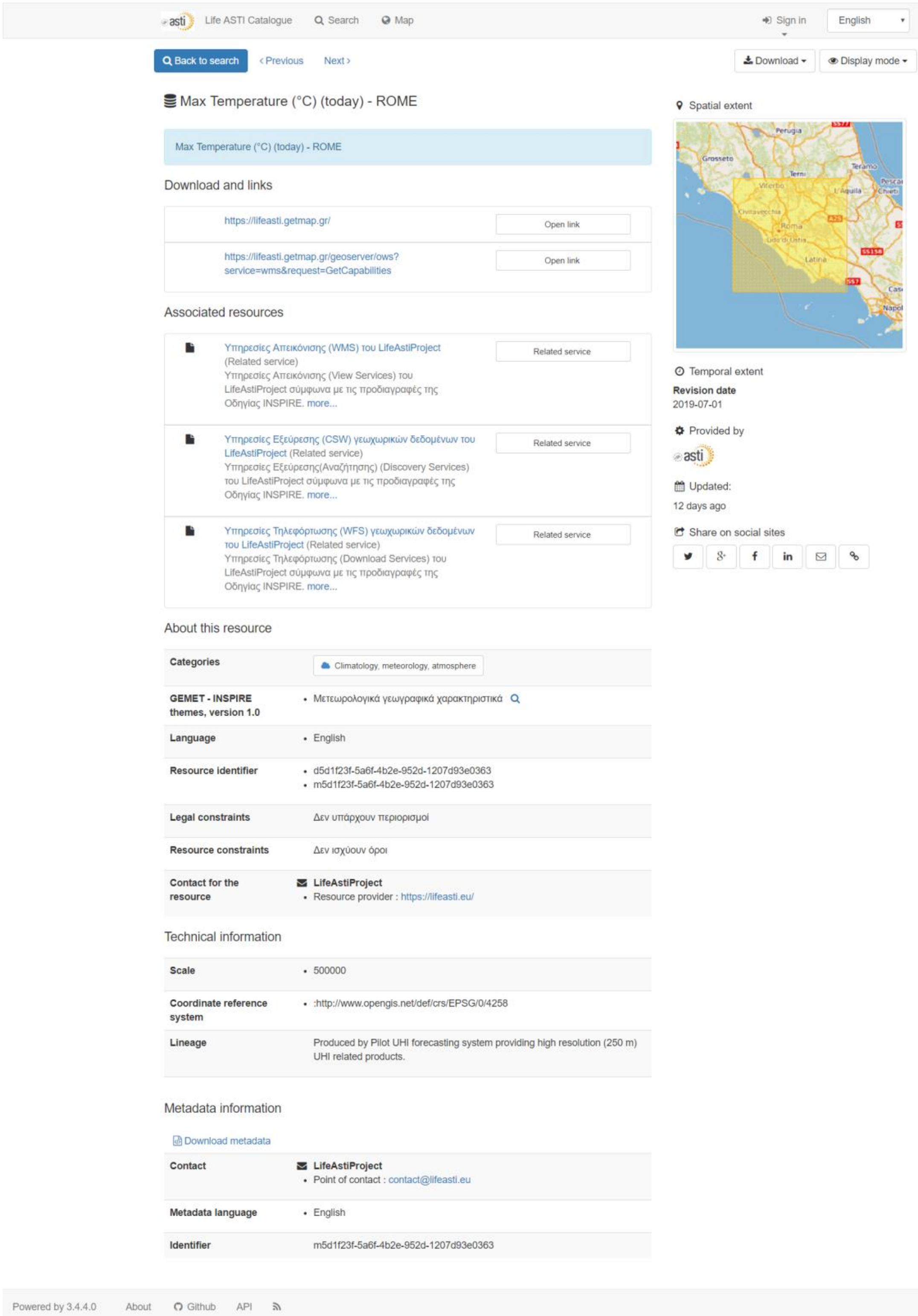


Figure 10: Geonetwork detailed information about a dataset

- Transformation Services

  The following services have been implemented:

  - Model data ingestion and spatial services. Implemented using python, gdal and the Geoserver REST API. The script runs automatically when new model results are available. It updates the layer definitions in the database, for each location and meteorological parameter, with the new data and metadata.
  - Aggregated statistics over city regions. Implemented using python. It uses the python libraries rasterio and rasterstats which provide access and tools for raster data analysis, like the zonal statistics function, which aggregates raster values over vector polygon areas. The aggregated values are stored in the database.
  - Point statistics. Implemented using python. It uses the python libraries rasterio and rasterstats to extract raster values at point locations which are then stored in the database.
  - Daily maps. Daily rasters of maximum concentration are produced from the hourly model data. The new datasets are published and exposed in Geoserver. Implemented using python and the Geoserver REST API.

b. Web application

The web application was developed using the php web programming language and the React.JS JavaScript library. It also uses the latest version of the Openlayers JavaScript library for map data visualization and ApexCharts.js for interactive graph plots. The application design is responsive in order for the information to be easily accessible in various devices (pc, laptop, tablet, smartphone), using different screen sizes and resolution. Figure 11 presents the home page of the forecasting system.

Figure 11: The HOME page of the LIFE ASTI forecasting system.

The general presentation rules for LIFE ASTI web applications have been applied regarding header / footer and CSS styles.

The home page welcomes users the forecasting system and provides access to the three forecast areas:

- Rome,
- Thessaloniki, and
- Heraklion.

The application menu, which is shown in all web pages, can also be used to navigate to different web sections / pages. The main information page is **"dashboard"**, which is available for each model area. Figure 12 gives an overview of the information presented there.

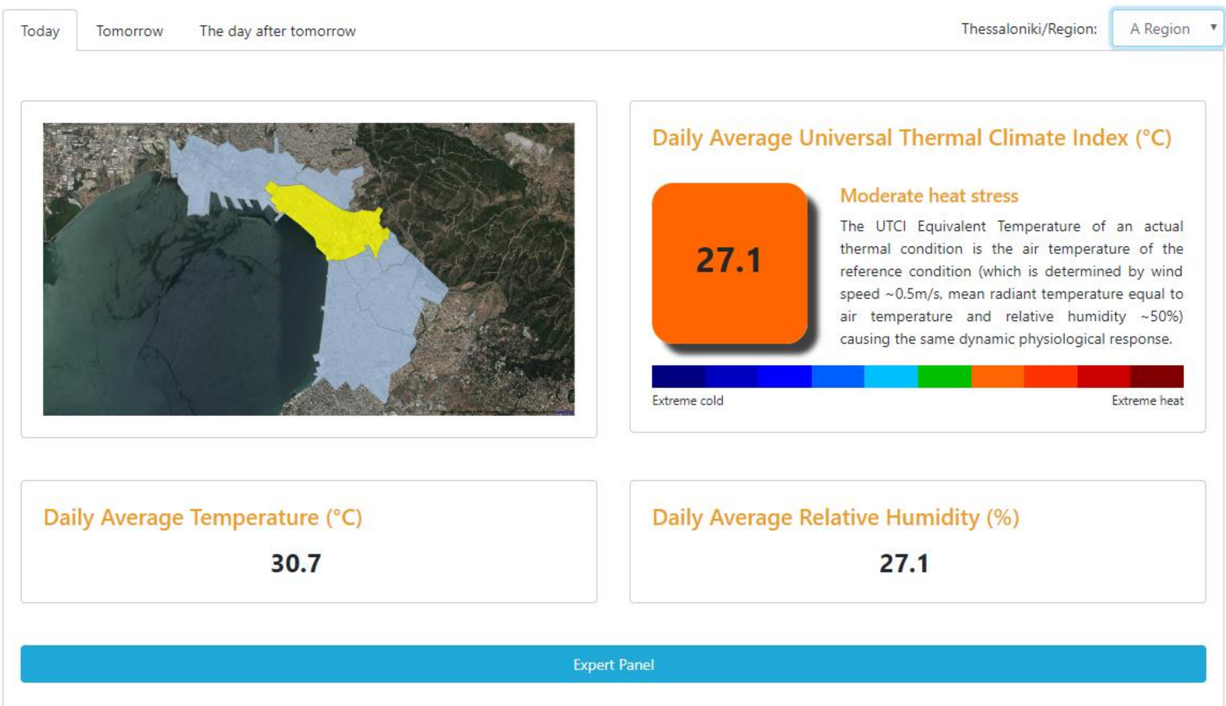


Figure 12: Overview of the forecast (dashboard).

Initially the users see the current (today) value of the Universal Thermal Climate Index. This index of thermal stress has been chosen as the most appropriate for informing the public about temperature conditions. Both text description, as well as the color of the box where the index value is given, are according to the color scale classes (from blue to green to red) which represents different thermal conditions.

In addition, the daily average temperature and relative humidity values are also presented. These values are aggregated over city areas which can be seen in the relevant map. The users are able to select another city area / district from the combo box at top / right, and the application will be updated with information for this location.

The users can also choose to see the results for tomorrow, or for the day after tomorrow, simple by selecting the TAB at the top / left of the page.

At the bottom of the page is the “Expert panel” button. By clicking on this, the page is extended with additional sections of information, valuable for the expert users. The expert panel information is presented in Figures 13, 14 and 15.

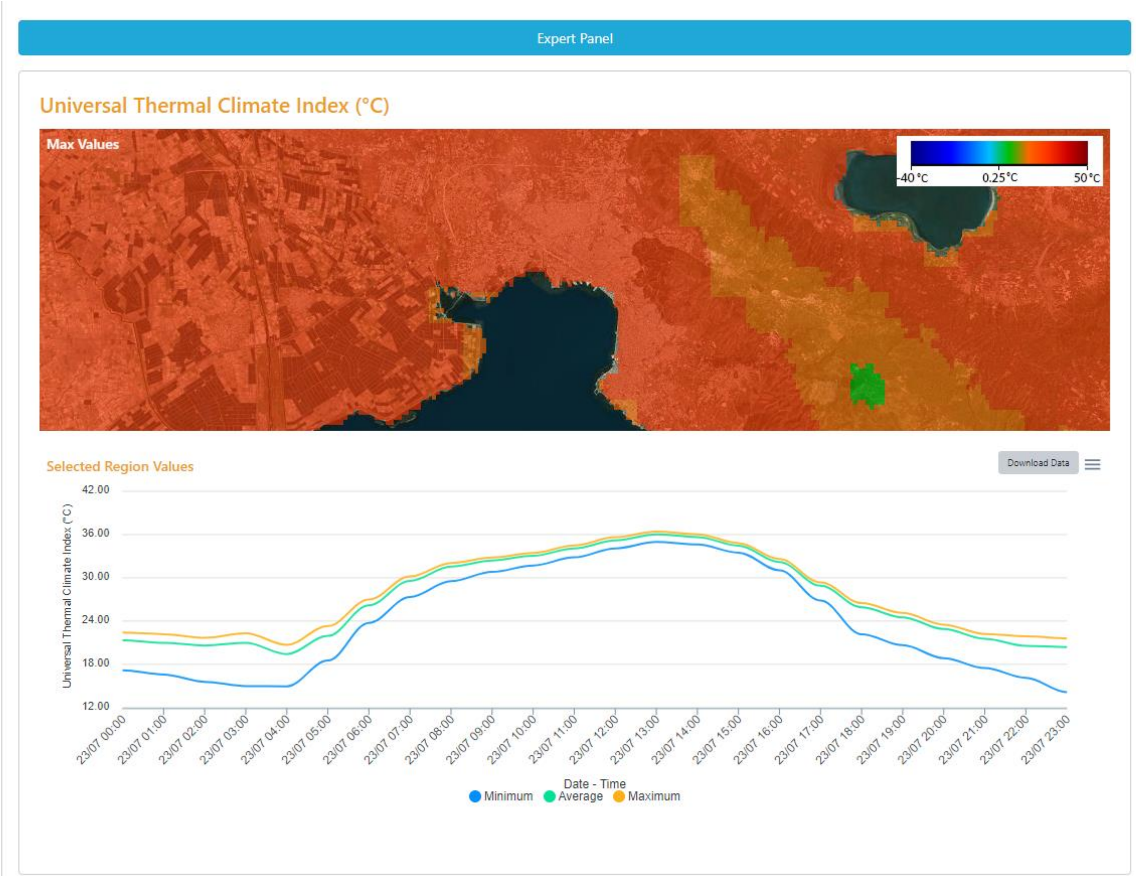


Figure 13: The expert panel, UTCI.

As it can be seen in Figure 13, the first section of the provided information is a map of the max values of the UTCI in the area. This map presents the maximum UTCI regardless of the time of its occurrence. The diagram just below the map displays the diurnal variation of the UTCI (max, mean, min) in the selected city area. The users are able to interact with the chart, download the data as csv file, or download the graph as png file.

The second section of the expert panel (Figure 14) provides information about the temperature. Like before, the map displays the spatial variation of the maximum temperature, while the chart shows the temporal, diurnal variation of the maximum, minimum and average temperature in the selected city area.

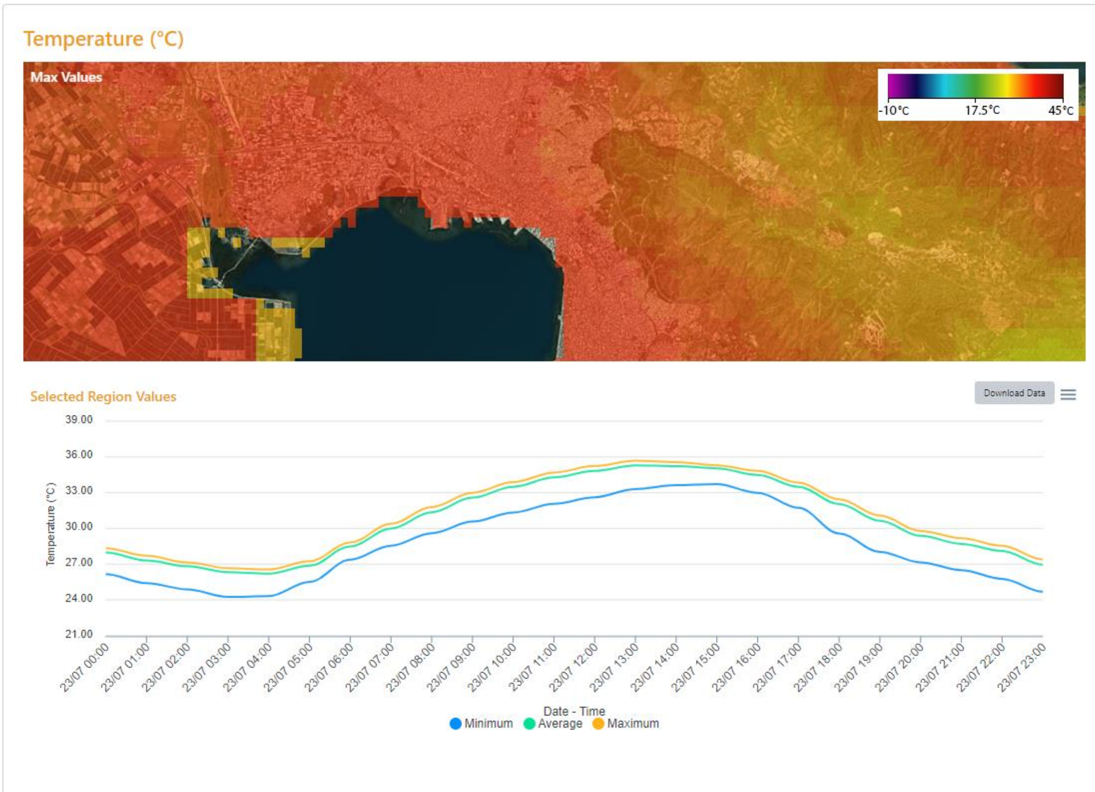


Figure 14: The expert panel, Temperature.

The third section (Figure 15) displays information about relative humidity, similar to the other 2 sections.

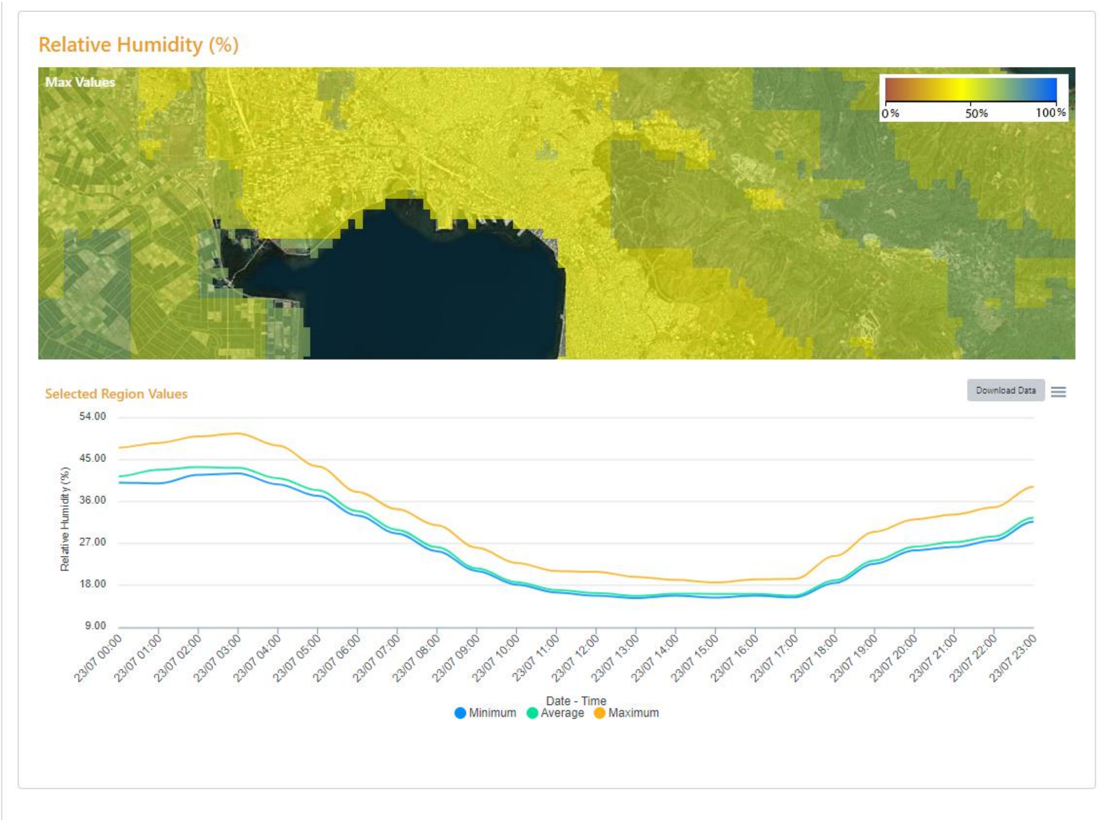


Figure 15: The expert panel, relative humidity.

When the user selects from the main manu **"map"** for one of the target areas, the application opens an interactive map viewer as shown in Figure 16.

Figure 16: Map View

The user interface is simple and intuitive in order to be easily used by non-expert users. There as an interactive map, in which the users can navigate (pan, zoom in / out) by just using their mouse, a layer panel (which can be opened or closed) and a time slider.

The time slider can be used to select the date and time for the data visualization. There is also an option to automatically change the time (map animation), using the play button (⊲) on the left.

Layer list provides access to all forecast parameters. By default, the UTCI is enabled (visible). The user can select any of these layers in order to be overlaid in the map by checking their visibility box.

Tip: Select only one layer each time for better visualization of the results.

The user can also change the layers opacity (transparency) by setting the relevant value using the provided slider. The other available options are to zoom to full layers extent, to change the color scale or to move the layer on top or below another layer.

Changing the color scale is a very useful functionality. By default, layers are displayed using a color scale suitable for every day of the year (ranging for example from very low to very high values). But, there are cases, where seasonal color scales provide a better spatial representation of the data. Changing color scales can be easily done by clicking on the relevant button. The map, as well as the legend image, are automatically updated.

The user can click at any map point in order to get information at that specific location (Figure 17).

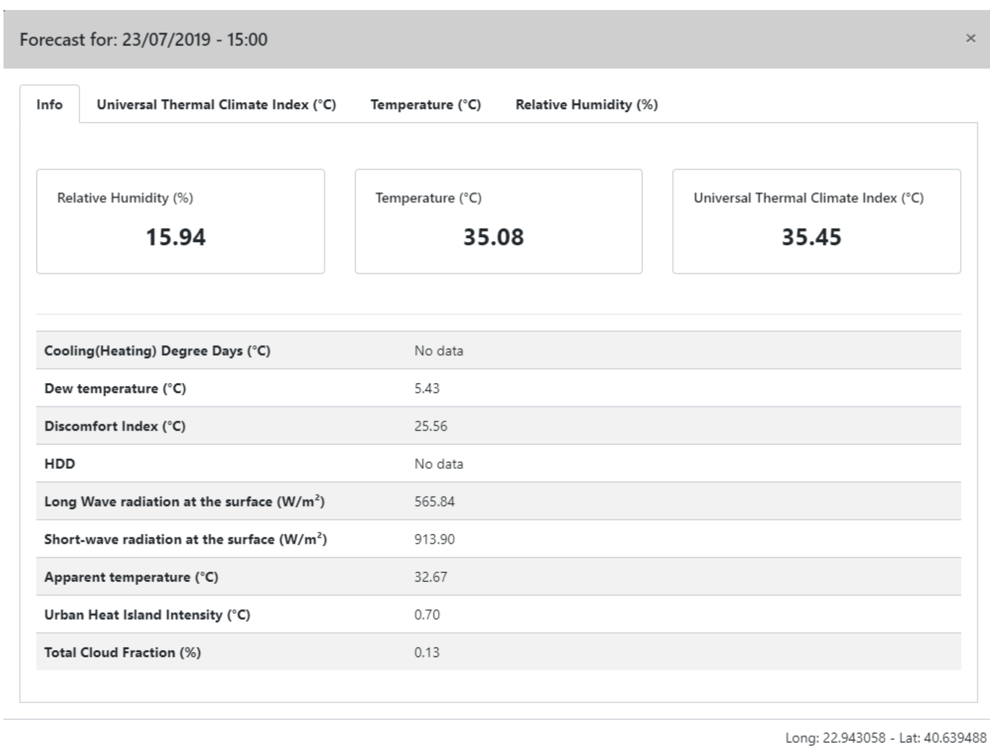


Figure 17: Information at point location, general info.

The first TAB of the pop-up form (Info) provides information for all forecasting parameters, for the selected location, date, and time. The other three TABS displays the temporal variation of UTCI, temperature, and relative humidity for the whole three days of the forecasting period (Figure 18).

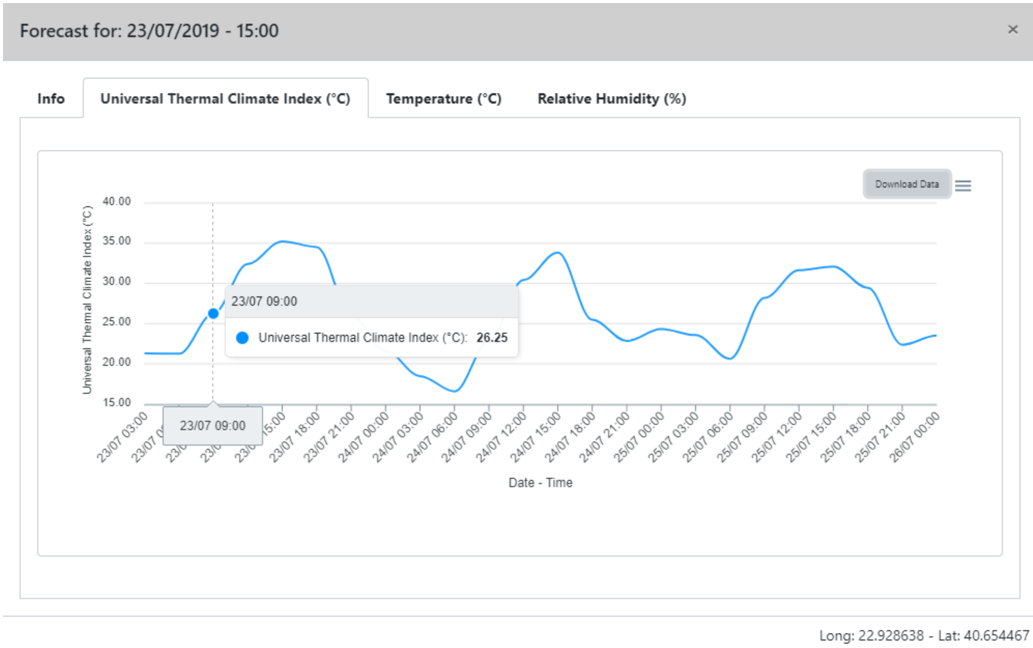


Figure 18: Information at point location, UTCI, temperature, relative humidity interactive charts.

The most advanced functionality of the map web page is the compare (Swipe) function. This can be enabled by selecting the **"S"** button on top / left of the map. In the pop-up form displayed the user selects the layer, the date, and time, of each dataset (left and right). When proceeding, the application displays a line which swipes the two layers, allowing the users to examine spatial variations between them (Figure 19).

Figure 19: Compare maps

The last functionality which is provided in the web application, is the metadata search. When the user selects **“METADATA”** from the applications menu, the system displays the form which is presented in Figure 20.

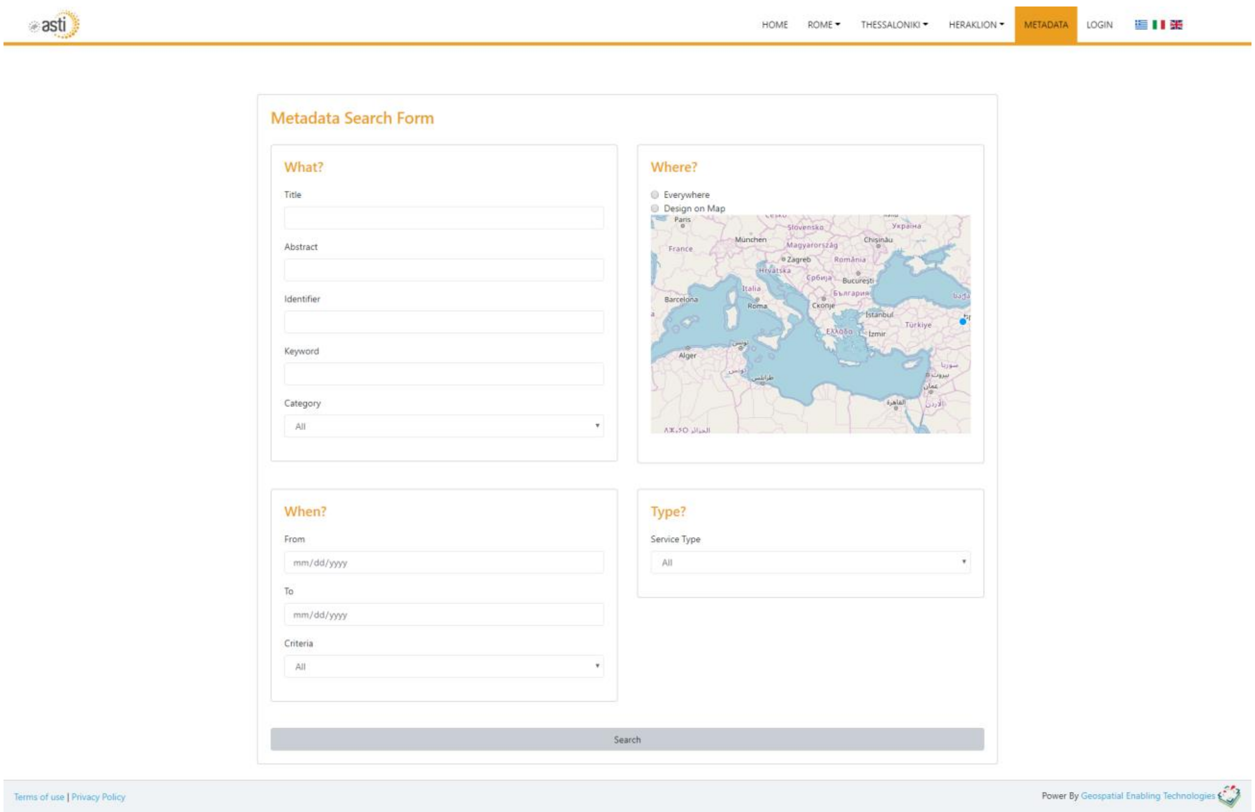


Figure 20: Metadata search form

For metadata search, the users must provide inputs related to What, When, Where and Type of data. Based on the metadata schema that was adopted, this information can be provided by several available input fields. Depending on their type, the user provides the search parameters as free text, selection from list or interactive from the map.

The results are displayed as data tiles, as it can be seen in Figure 21. For example, for this search, the user selected to search for temperature related meteorological data around Thessaloniki. Thus, he provided input in title and category as well as a bounding box of the search area.

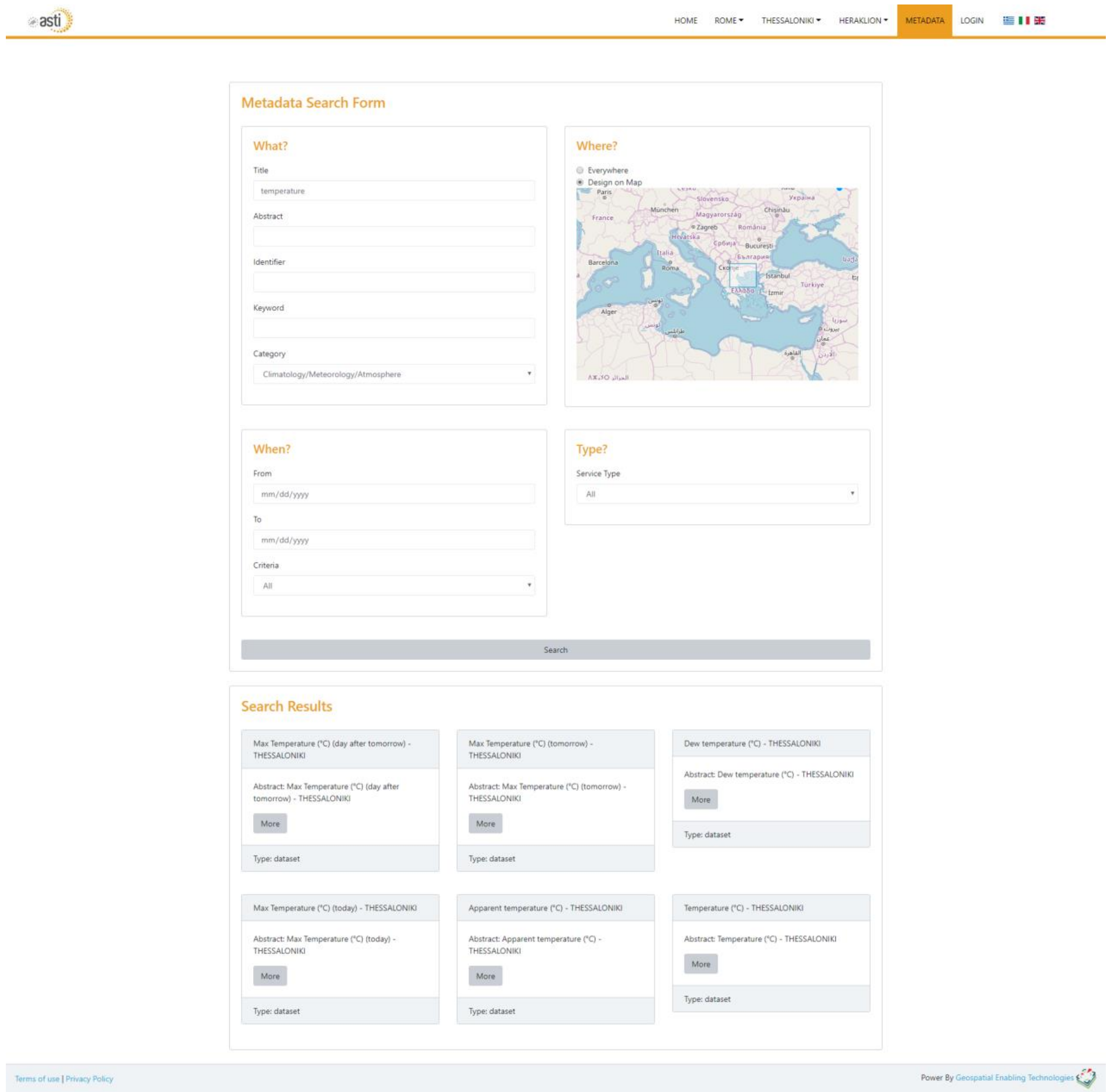
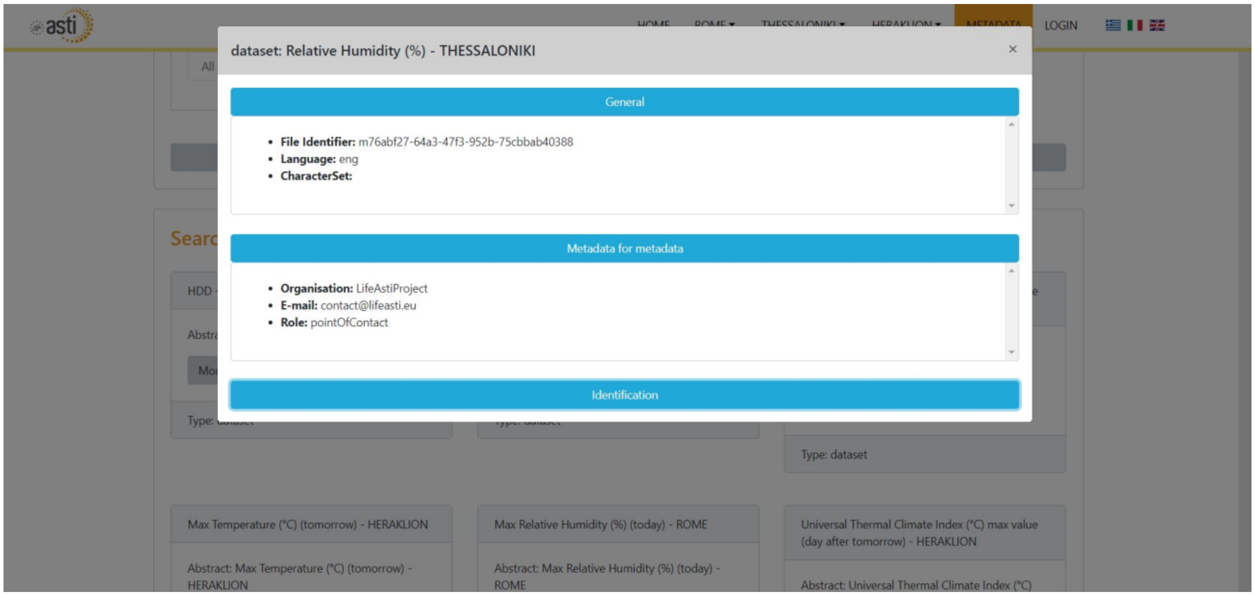


Figure 21: Metadata search results.

By selecting **"More"** in a dataset, detailed metadata information is presented (Figure 22). The user can also download the metadata information as an XML file.



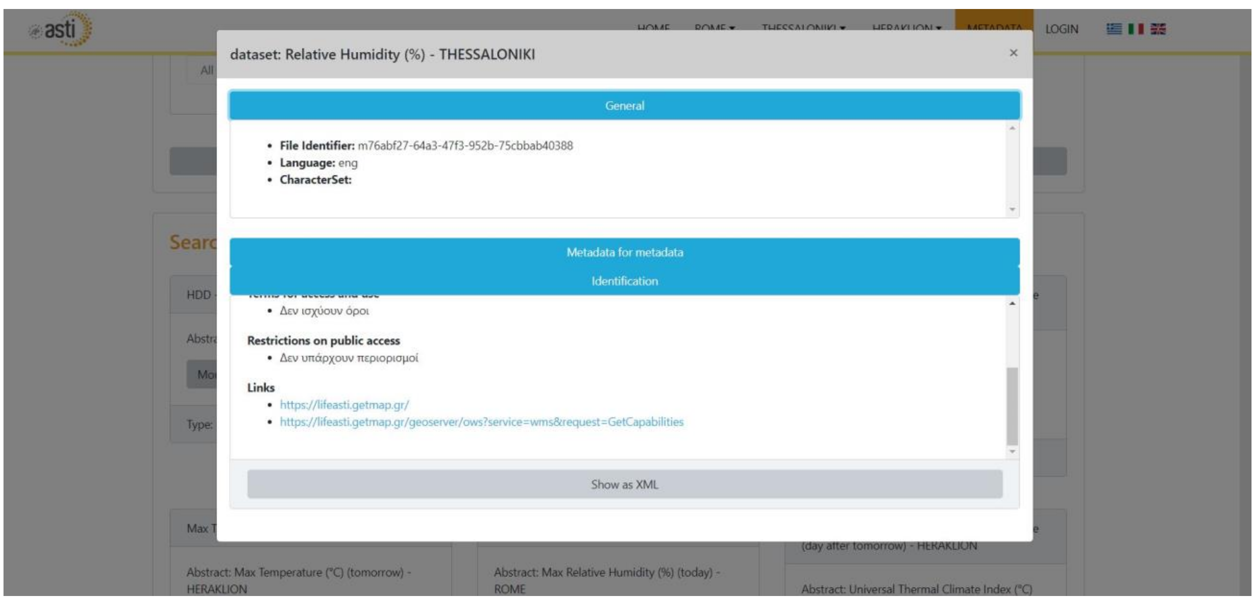


Figure 22: Layers metadata details.

Finally, the application provides user registration option (Figures 23-24).

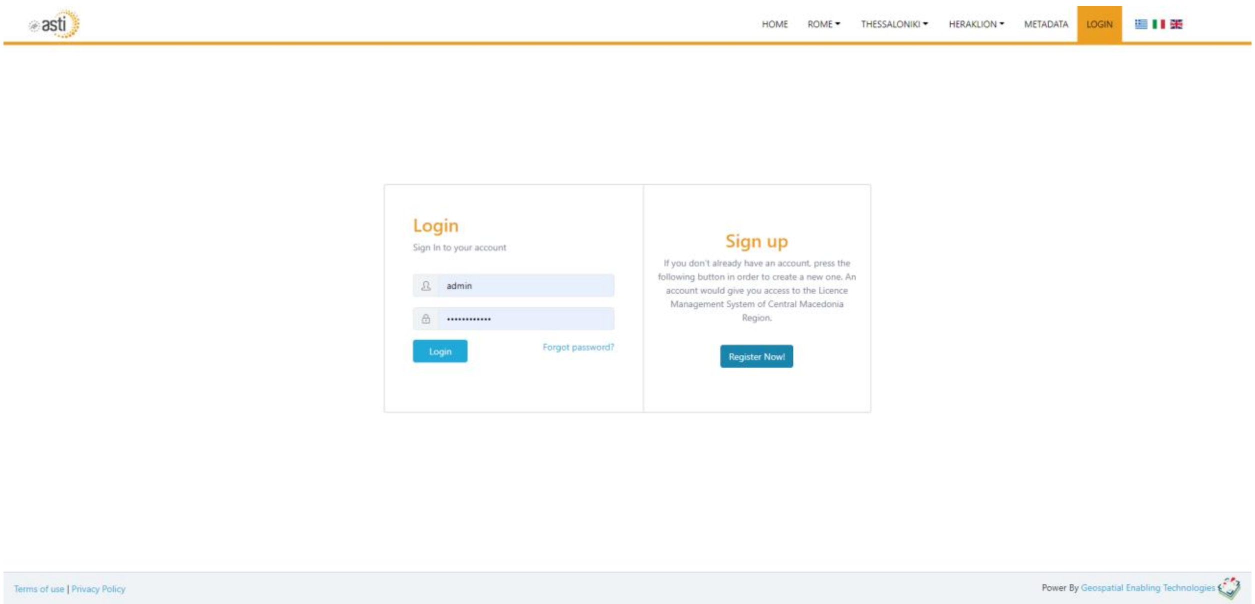


Figure 23: Users login / registration.

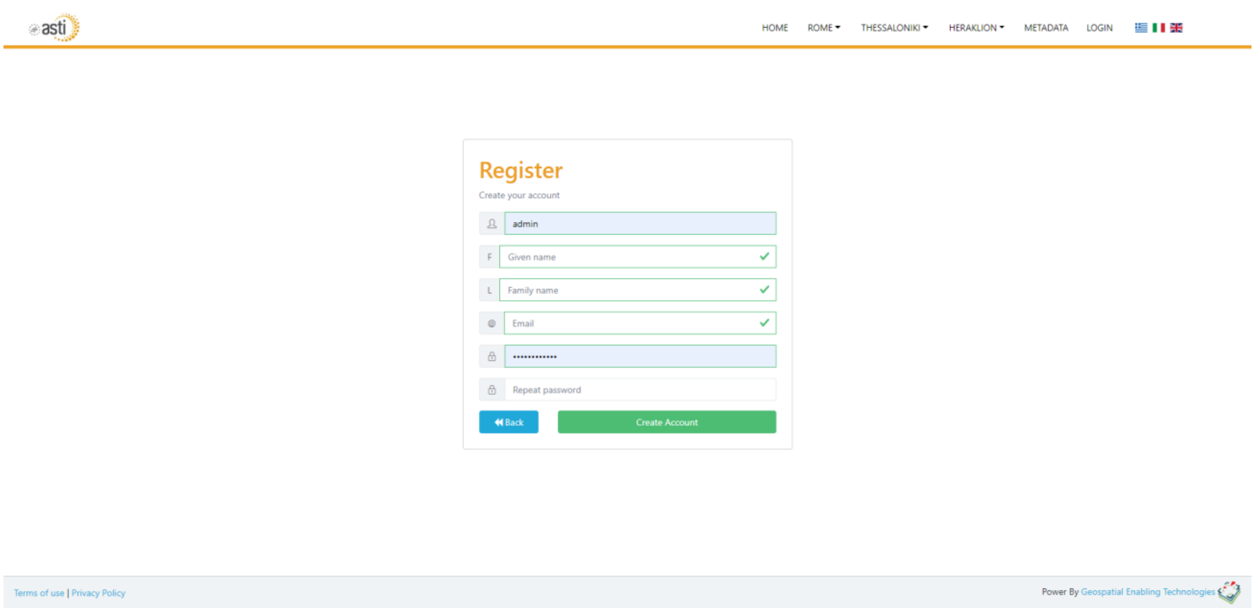


Figure 24: New user registration form

Registered users can access personalized information (in the mobile app), or sensitive information (for public authorities or other relevant stakeholders).

c. Mobile application

The mobile application was developed using the **REACT-NATIVE** framework. React-Native supports the development of native mobile applications using only JavaScript. It uses the same design as React, letting programmers compose a rich mobile UI using declarative components. The apps that have been developed with React Native aren't mobile web apps because React Native uses the same fundamental UI building blocks as regular iOS and Android apps. So, instead of using Swift, Kotlin or Java, programmers can put those building blocks together using JavaScript and React.

The mobile application was developed using the specifications of the LIFE ASTI architectural and functional report. Figure 25 presents the home screen of the mobile application in which the users can navigate to one of the available forecasting areas.

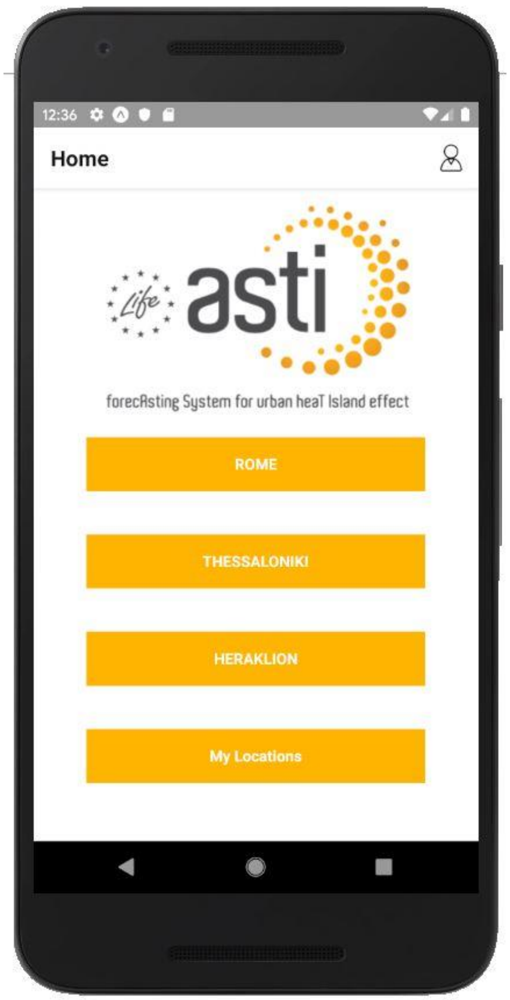


Figure 25: The area selection page of the mobile app.

By selecting an area, the application displays the overall forecasting information, like the web dashboard presented before (Figure 26).

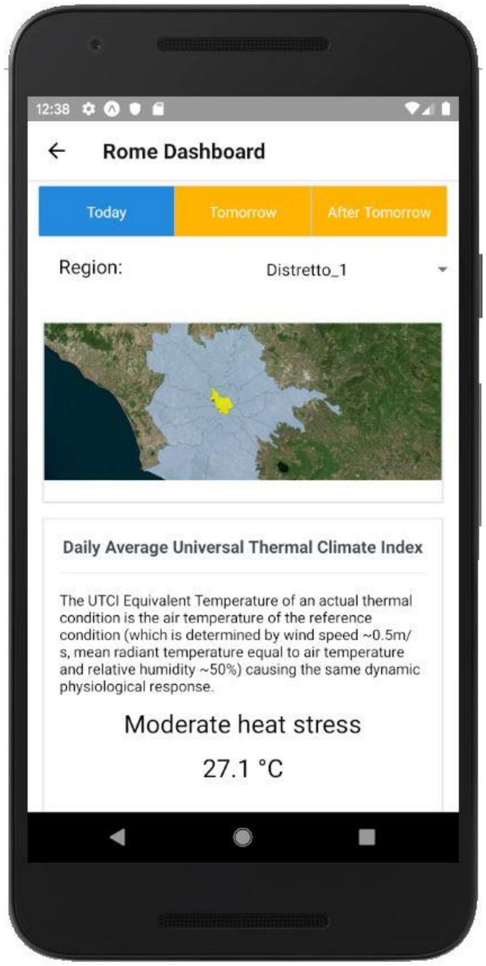


Figure 26: The mobile city dashboard.

The users can access the data for today, tomorrow, or the day after tomorrow. For each day the value of the UTCI is provided along with personalized information about the thermal risk and the precaution measures. Diurnal variation of the UTCI and temperature is also provided. The values are given for city regions which are displayed also in a map. The users can choose another city region and the relative information is automatically updated in the app.

The details section launches the map page (Figure 27). The map page has similar UI and functionality with the web map page. The users are able to select a forecast parameter, which is then overlaid in the map. They can also select the reference day and time from the time slider at the bottom of the page.

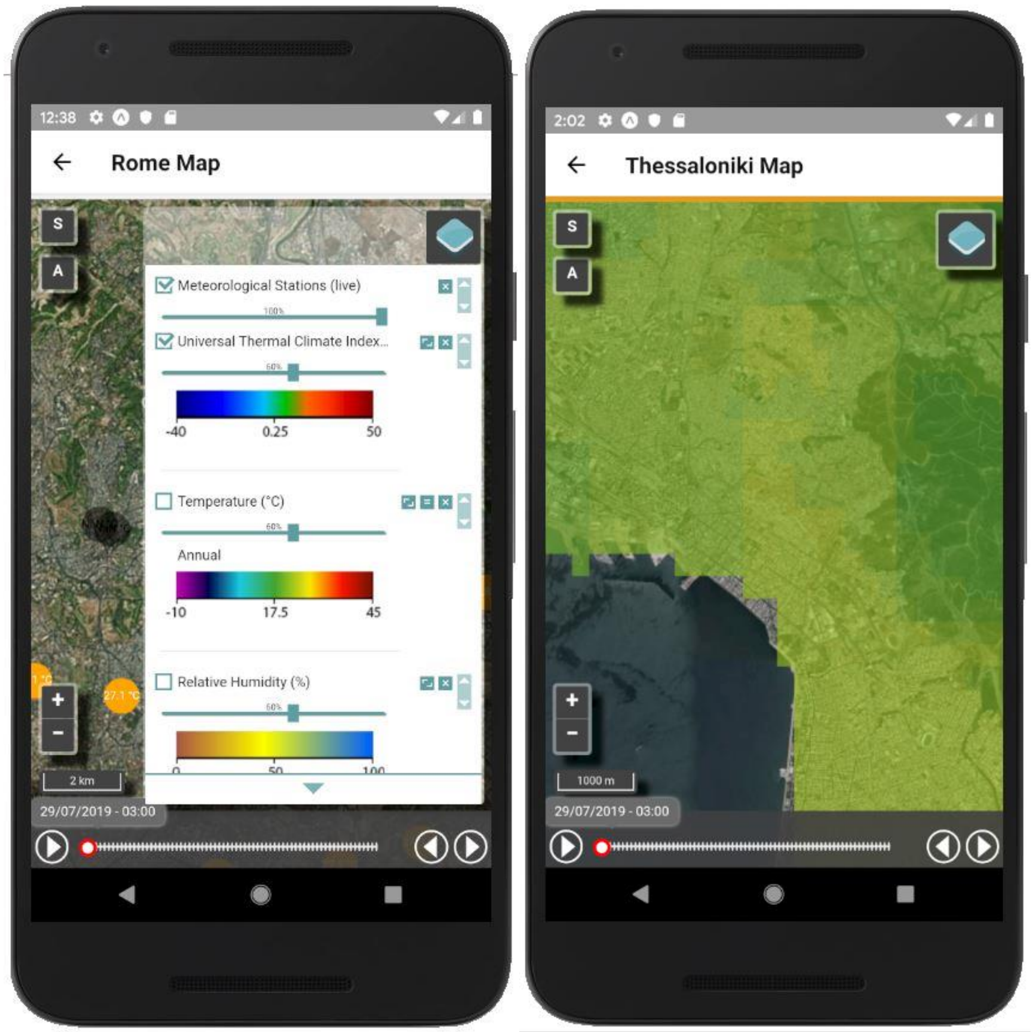


Figure 26: Map visualization of data.

Although most of the data is freely available for all, in order to provide personalized information, registered users are required. The users can easily create a login account by fill in the requested information in the sign-up form (Figure 27).

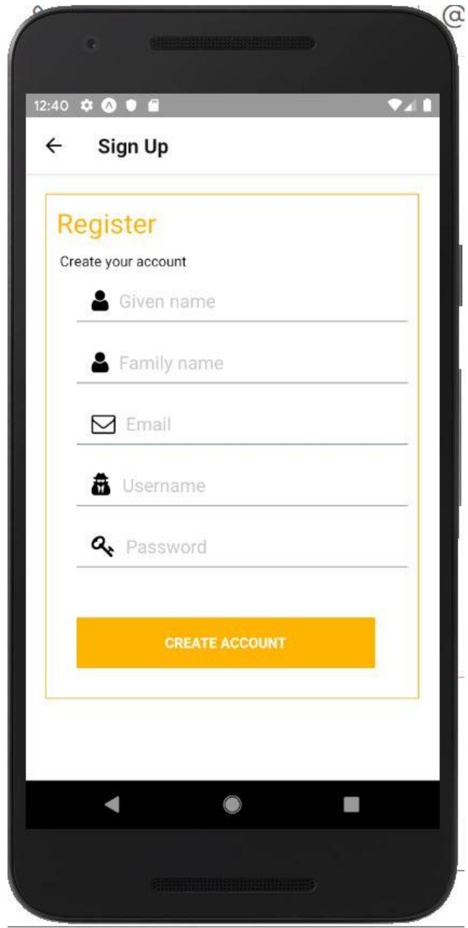


Figure 27: The user sign-up form.

To complete the user profile, the users are requested also to provide additional information about their age and their health condition.

To login, they simply enter their user name and password (Figure 28).

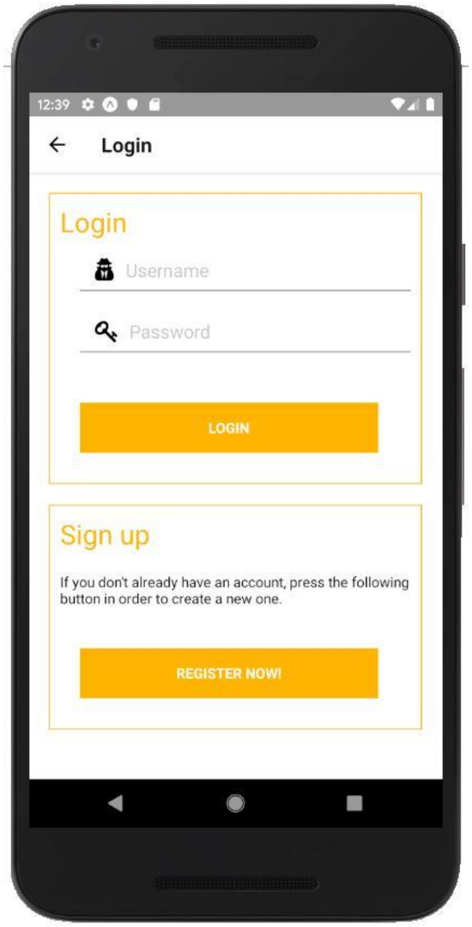


Figure 28: The user login form.

In addition, the application enables registered users to store their favorite locations in order to have quick access to forecasting data at that points. The selection of location is performed interactively from a map as shown in figure 29. The GPS location can be also used as an input.

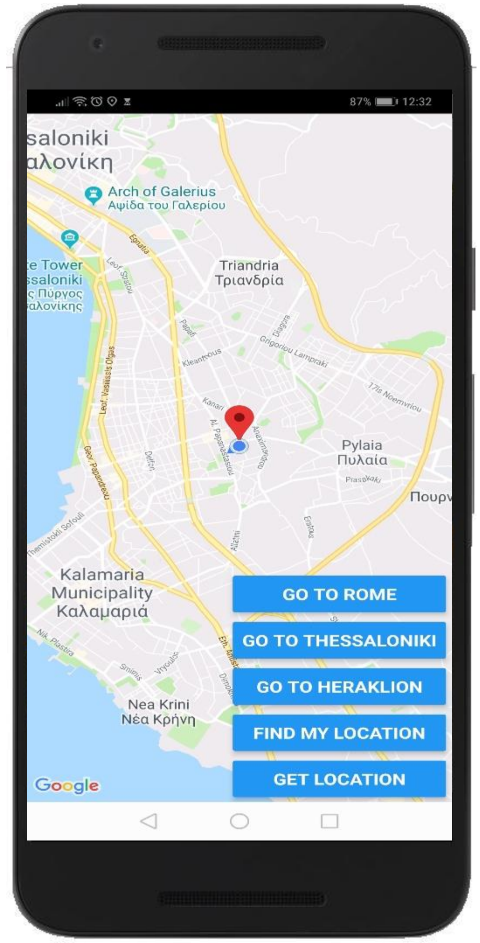


Figure 29: Custom location selection form

The information for each location is then shown under the “My location” list (Figure 30)

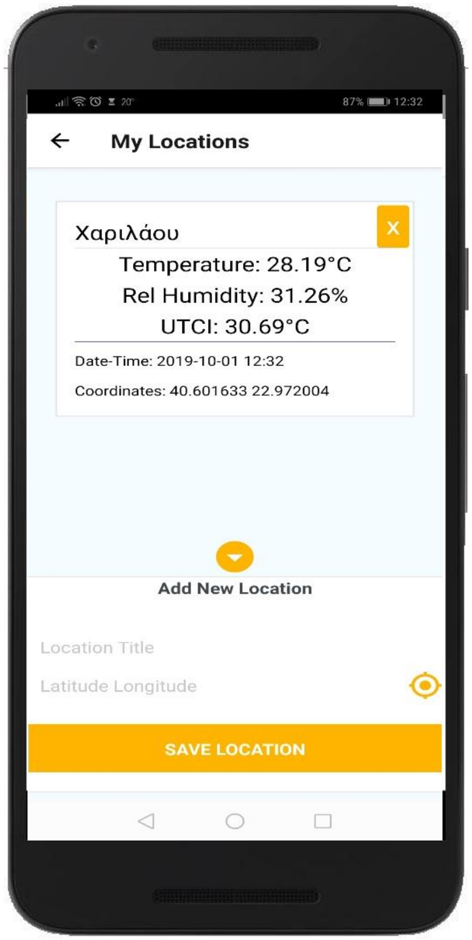


Figure 30: Forecast information at user's locations

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System
for urban
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effect

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