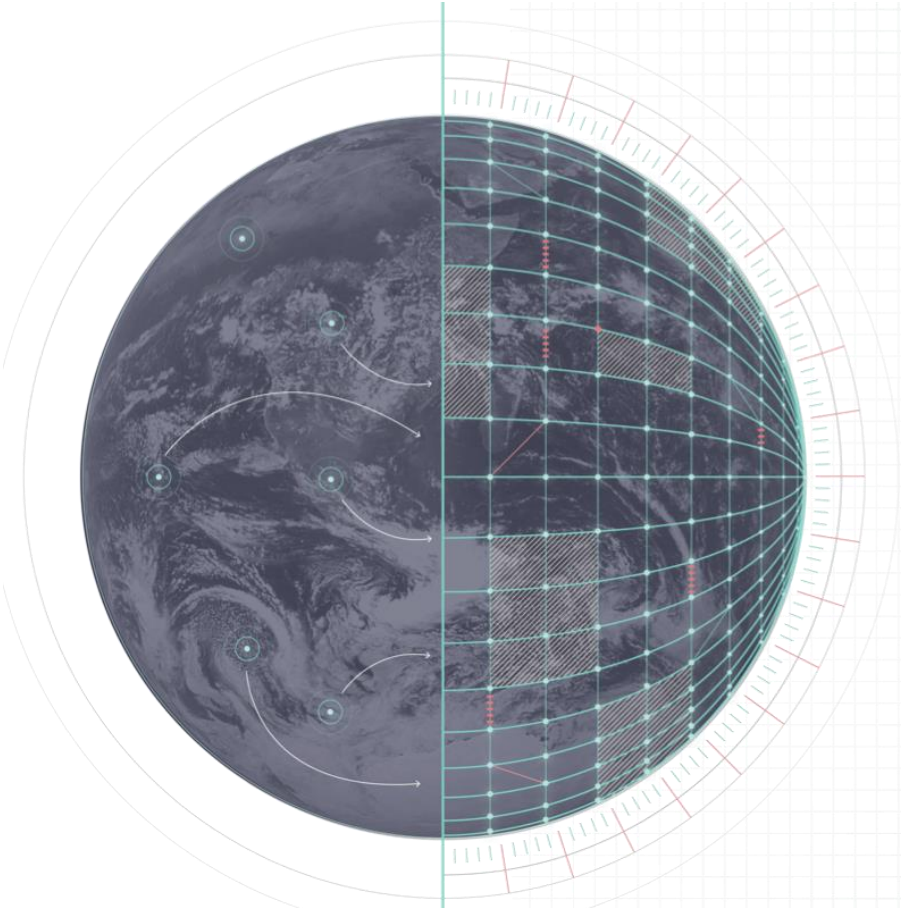


DESTINATION EARTH

URBAN HEAT USE CASE OVERVIEW

Nele Veldeman, Dirk Lauwaet, Filip Lefebre, Wim Peelaerts

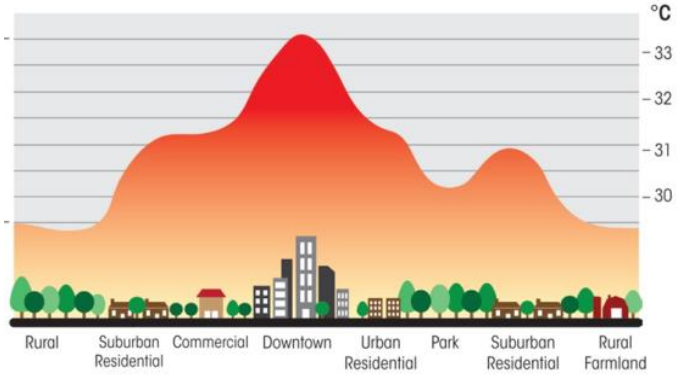
VITO

Funded by the European Union

Destination Earth implemented by ECMWF esa EUMETSAT

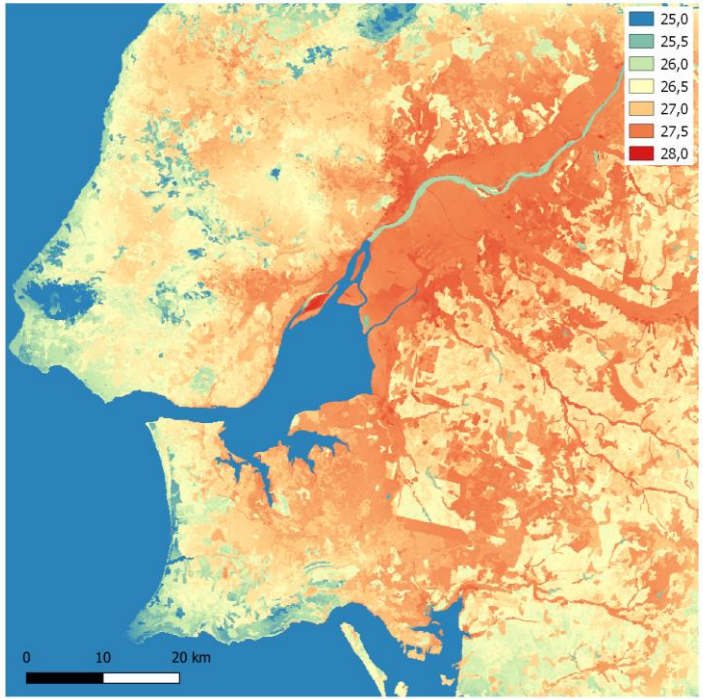
Context

- Climate change leads to increasingly frequent and intense heatwaves in Europe
- Cities are especially at risk because of the urban heat island (UHI) phenomenon



Objectives

- Deliver **high-resolution urban heat maps** for cities across Europe to underpin and motivate urban climate adaptation measures that are being developed
  - Support **EU adaptation policy** intended to increase urban resilience against projected exposure to extreme heat
  - Support **local administrations** to take efficient heat stress adaptation measures at the most vulnerable locations



Average daily maximum WBGT during heatwave days [°C]. Source: VITO.

REGIO

PRAHA PRAGUE PRAGA PRAG

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área metropolitana de lisboa

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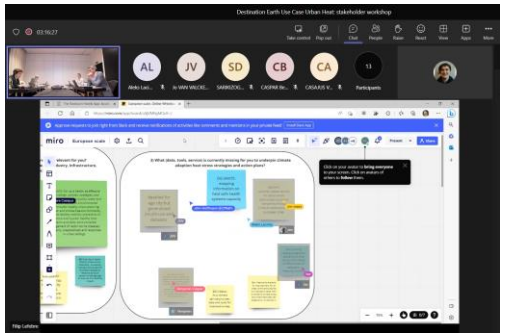
Urban Heat Service - Output

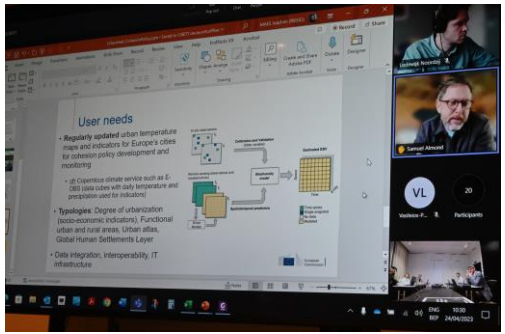
- **Heat stress calculations** for
  - 2011-2020 (ERA5)
  - 2020-2040 (Climate DT) at 100m resolution

- **Advanced heat stress variables:** WBGT, UTCI, Tapp

- **Output indicators**: UHI intensity, # tropical nights, # health heatwave days, Exposure to heatwaves, Heat-related mortality, Exceedances of health threshold levels, Lost working hours and Cool island identification

- **Impact of climate adaptation measures**: green roofs, light colouring, urban trees, soil unsealing, …





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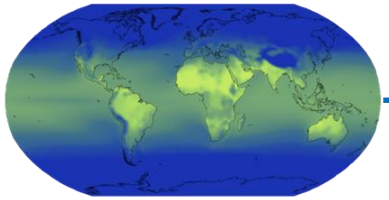
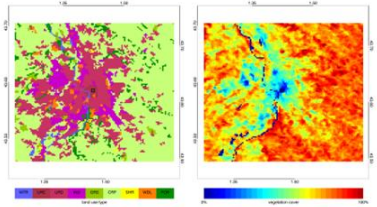
Urban Heat Service – UrbClim model

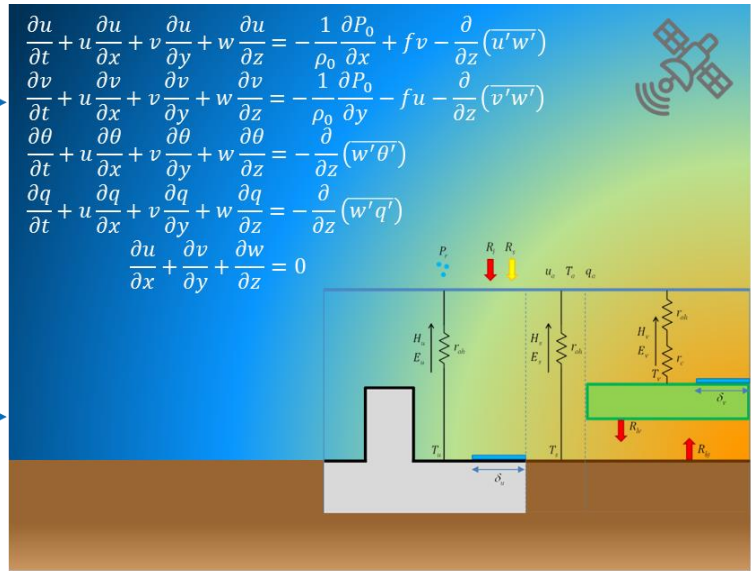


large-scale atmospheric parameters (re-analysis, climate projection)

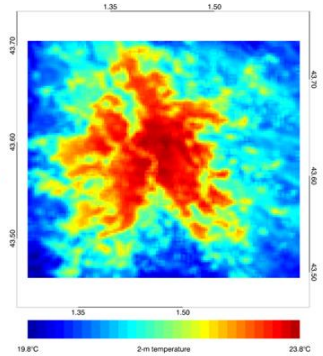


terrain parameters (land cover, vegetation %, ...)

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P_0}{\partial x}+fv-\frac{\partial}{\partial z}\left(\overline{u'w'}\right)$$
$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P_0}{\partial y}-fu-\frac{\partial}{\partial z}\left(\overline{v'w'}\right)$$
$$\frac{\partial \theta}{\partial t}+u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+w\frac{\partial \theta}{\partial z}=-\frac{\partial}{\partial z}\left(\overline{w'\theta'}\right)$$
$$\frac{\partial q}{\partial t}+u\frac{\partial q}{\partial x}+v\frac{\partial q}{\partial y}+w\frac{\partial q}{\partial z}=-\frac{\partial}{\partial z}\left(\overline{w'q'}\right)$$
$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$



De Ridder et al., 2015. https://doi.org/10.1016/j.uclim.2015.01.001



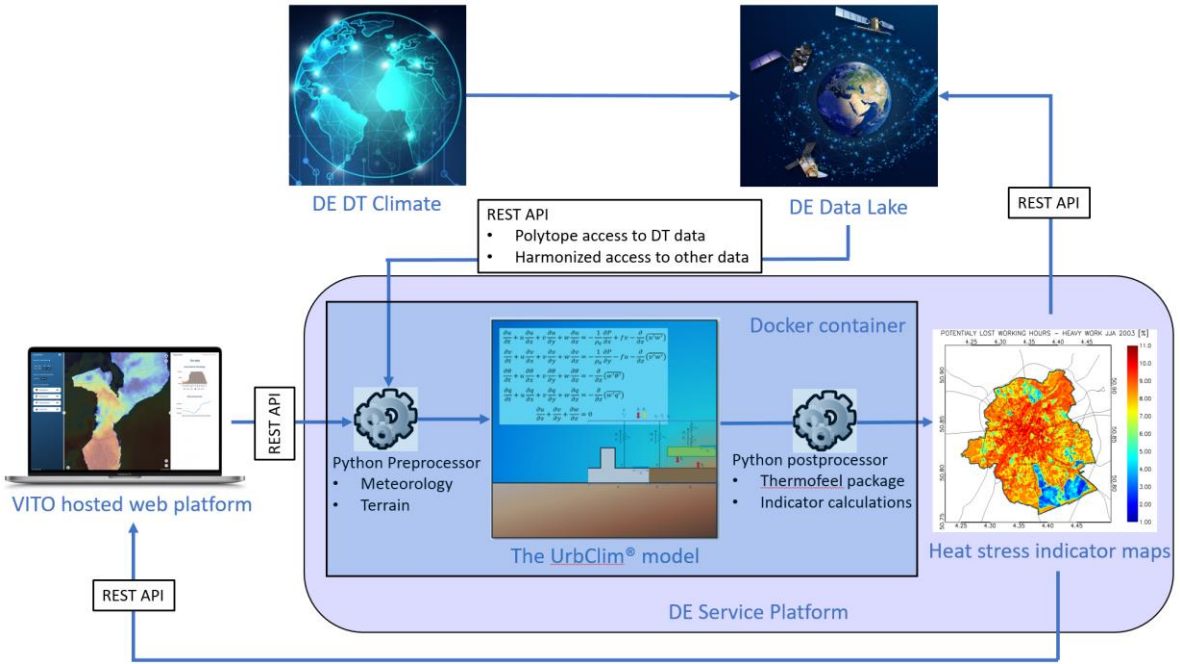
hourly gridded (100-m)

- temperature
- humidity
- wind speed
- energy & water fluxes
- plant water stress
- soil moisture content
- ...

inputs — URBCLIM® — ouputs

Urban Heat Service – DestinE

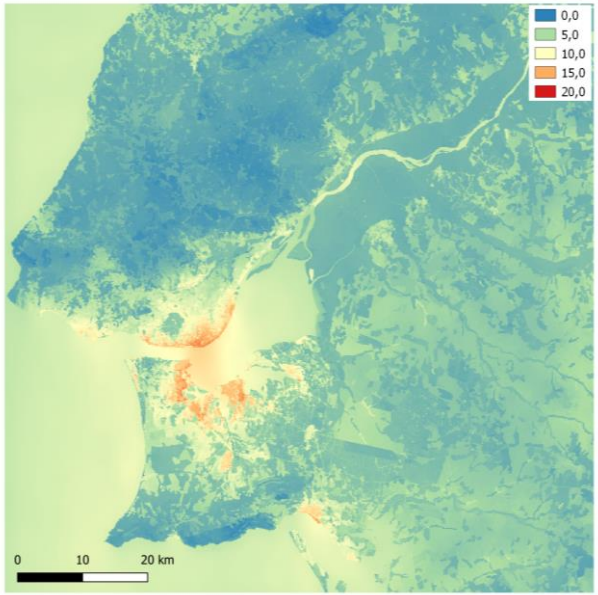
- UrbClim will be nested within **output provided by** models in the **Digital Twin** platform
- UrbClim will **access required data** via the **Data Lake**
- The service will make use of the **Digital Twin Engine interfaces**
- The service will be provided via **Destination Earth's Services Platform**



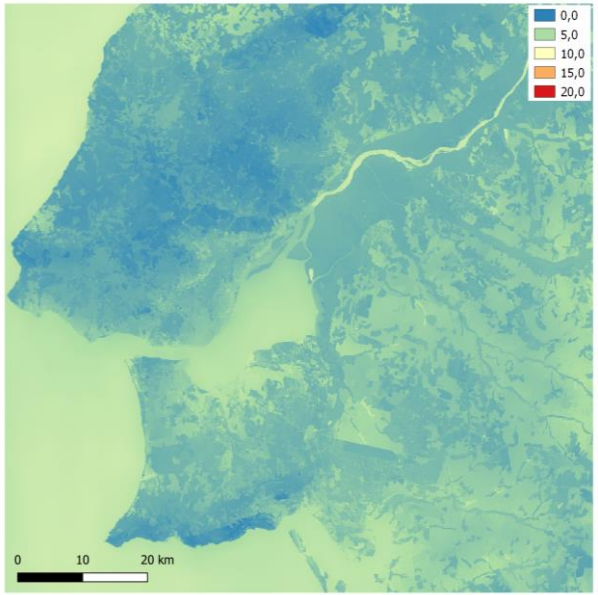
Urban Heat Maps & Indicators

Average number of tropical nights

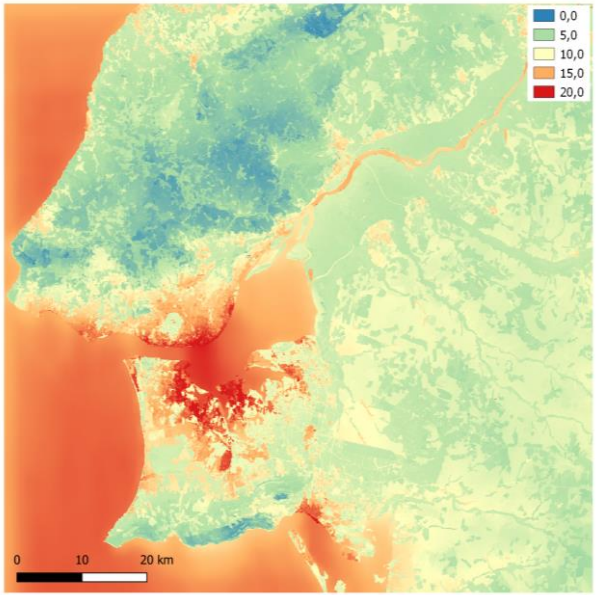
number of days during which the nighttime minimum air temperature is higher than 20°C



ERA5 2011-2020 Reference



ERA5 2011-2020 MAX scenario

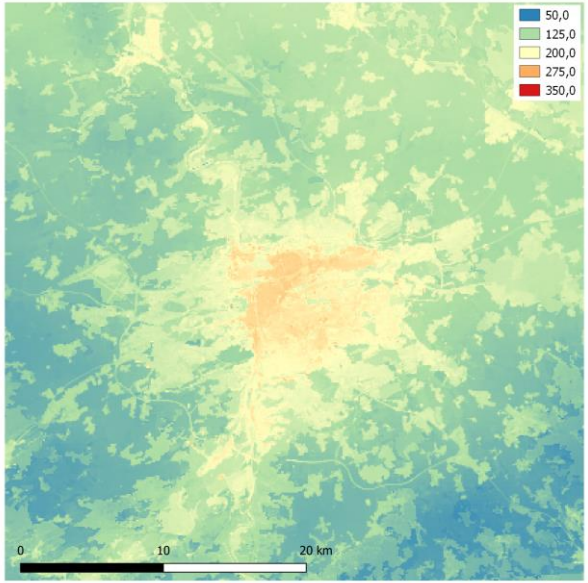


IFS-NEMO SSP3-7.0 2031-2040

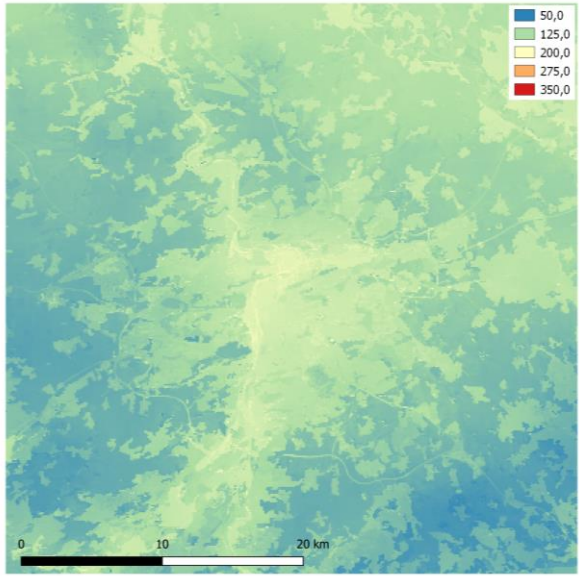
Urban Heat Maps & Indicators

Heat-related excess mortality

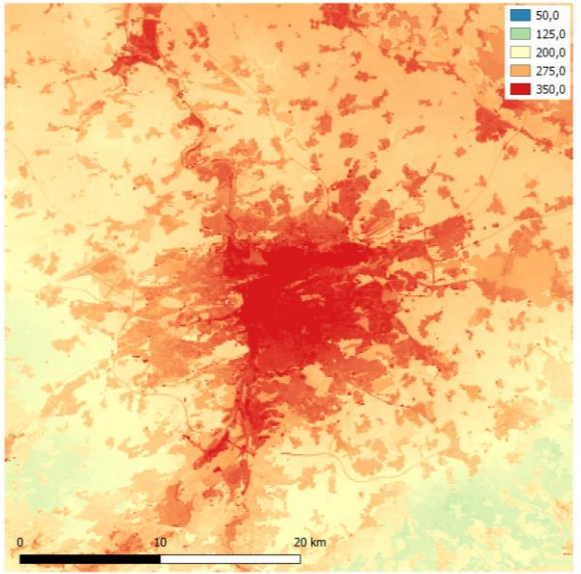
calculated based on the paper of Urban et al. (2022) where excess mortality in Prague is linked to daily average air temperatures



ERA5 2011-2020 Reference



ERA5 2011-2020 MAX scenario



IFS-NEMO SSP3-7.0 2031-2040

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Impact Assessment

Impact of climate change

Lisbon Metropolitan Area - annual average values (urban areas only)			
Heat stress indicators	**Reference**	**2031-2040 SSP3-7.0 IFS-NEMO**	
			Relative change [%]
Urban Heat Island [°C]	2,11	2,11	0,00
Health Heat Wave Days	5,97	5,28	-11,58
Tropical Nights	6,96	11,99	72,20
Days with UTCI > 26°C	178,77	184,34	3,11
Days with WBGT > 25°C	13,85	17,08	23,34
Lost Working Hours for intense manual work	12,14	29,99	146,96
Heat-related mortality	228,52	257,24	12,57

Impact of adaptation measures

Lisbon Metropolitan Area - 2011-2020 annual average values (urban areas only)							
Heat stress indicators		**Adaptation scenarios**					
	Reference	**Green Roofs**	**Light-colored materials**	**Soil unsealing**	**Urban Trees**	**Combination of all**	**Max impact [%]**
Urban Heat Island [°C]	2,11	1,99	1,96	1,92	2,09	1,70	-19,66
Health Heat Wave Days	5,97	6,11	5,35	6,00	6,07	6,22	-10,42
Tropical Nights	6,96	5,27	6,25	4,81	6,60	3,23	-53,64
Days with UTCI > 26°C	178,77	165,06	184,11	175,60	157,65	140,26	-21,54
Days with WBGT > 25°C	13,85	12,79	12,97	14,16	11,47	10,18	-26,46
Lost Working Hours for intense manual work	12,14	11,09	11,04	12,64	9,07	7,73	-36,32
Heat-related mortality	228,52	214,32	209,83	209,78	227,05	186,58	-18,35

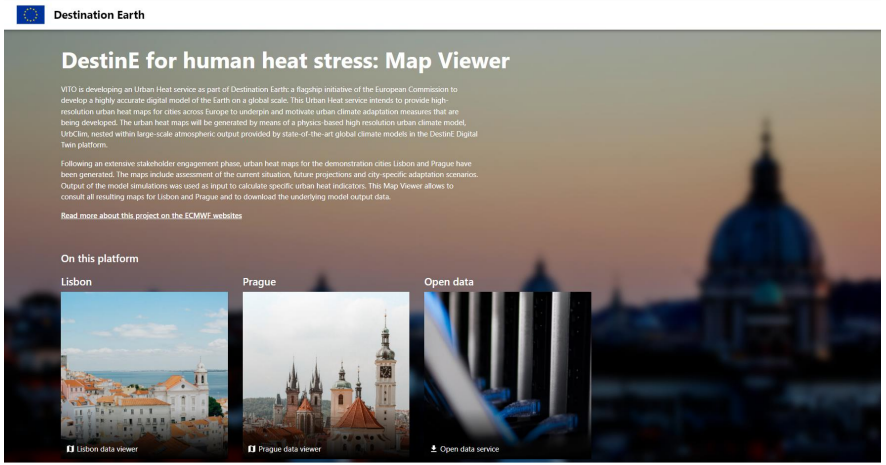
Conclusions

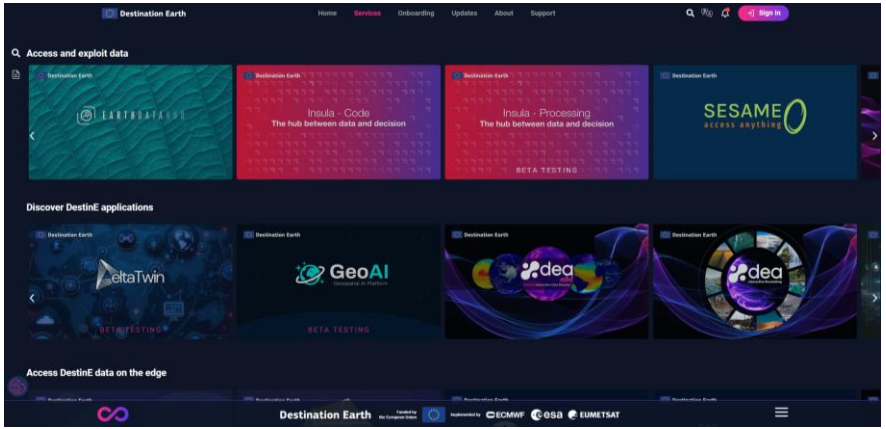
- Climate change will have a **negative impact on most heat stress indicators**, but the severity depends on which indicator you consider (air temperature and extreme event-related indicators are impacted the most)
- Locally applied **adaptation measures can have a significant positive effect** on (most) heat stress indicators
- For some heat stress indicators, the impact of these (very ambitious) adaptation measures is expected to be **able to compensate** for the climate change impact up to 2040
- There is **no 1 'fit-for-all' measure**, the combination of measures generates the strongest overall response
- But (outdoor) adaptation measures are **no magical solution**, at some point climate change becomes too strong to keep the status-quo => also focus on building-level measures, cool shelters, heat action plans,…

Outlook

- Project ends by the end of this month
  - Finish web platform
  - Start onboarding this service in DestinE Service Platform

- Proposal to continue this work in new Destination Earth project
  - **Make it a service** (any city in the world, full automatization, further integration in DestinE, small cost for users,…)
  - **Add user-requested functionalities** (e.g. very high resolution heat stress maps, customized adaptation measures, customized input data selection, …)





https://platform.destine.eu/services/

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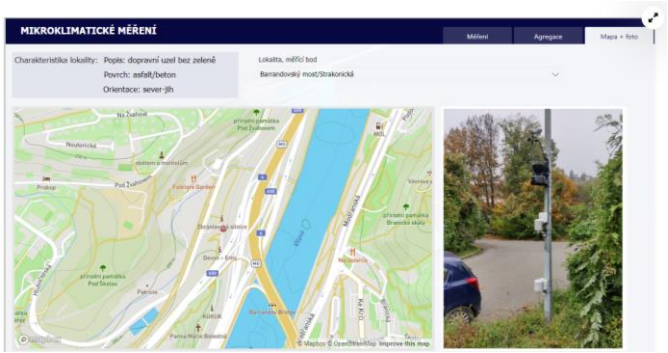
https://stories.ecmwf.int/destination-earth-use-case/

nele.veldeman@vito.be – filip.lefebre@vito.be – dirk.lauwaet@vito.be

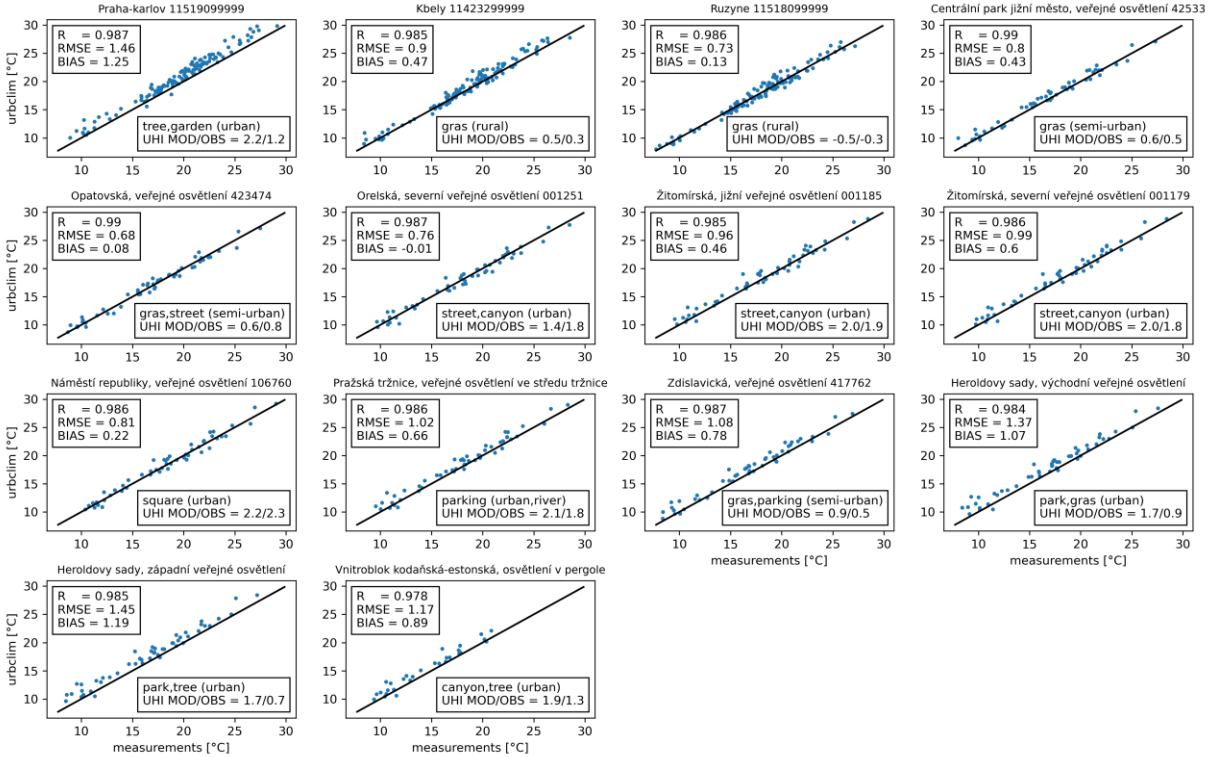
Extra slides

UrbClim validation

- UrbClim model results have been validated against 14 local measurement stations in Prague for the summer of 2022



https://golemio.cz/data/mikroklimaticke_parametry



Comparison between observed and modelled daily average 2m air tem

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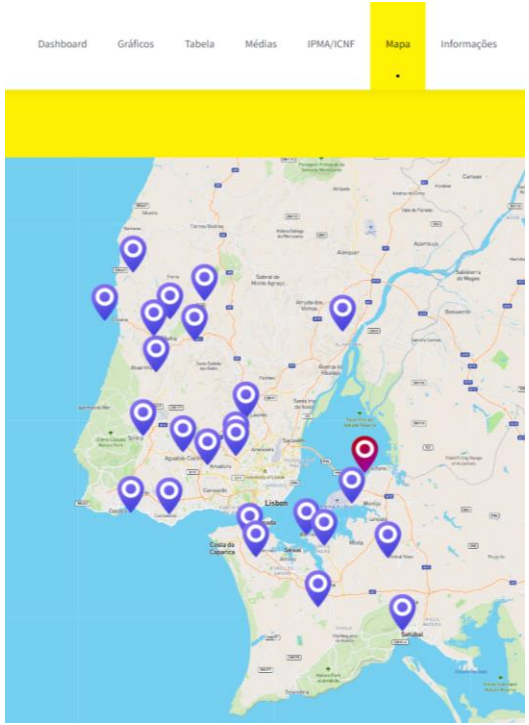
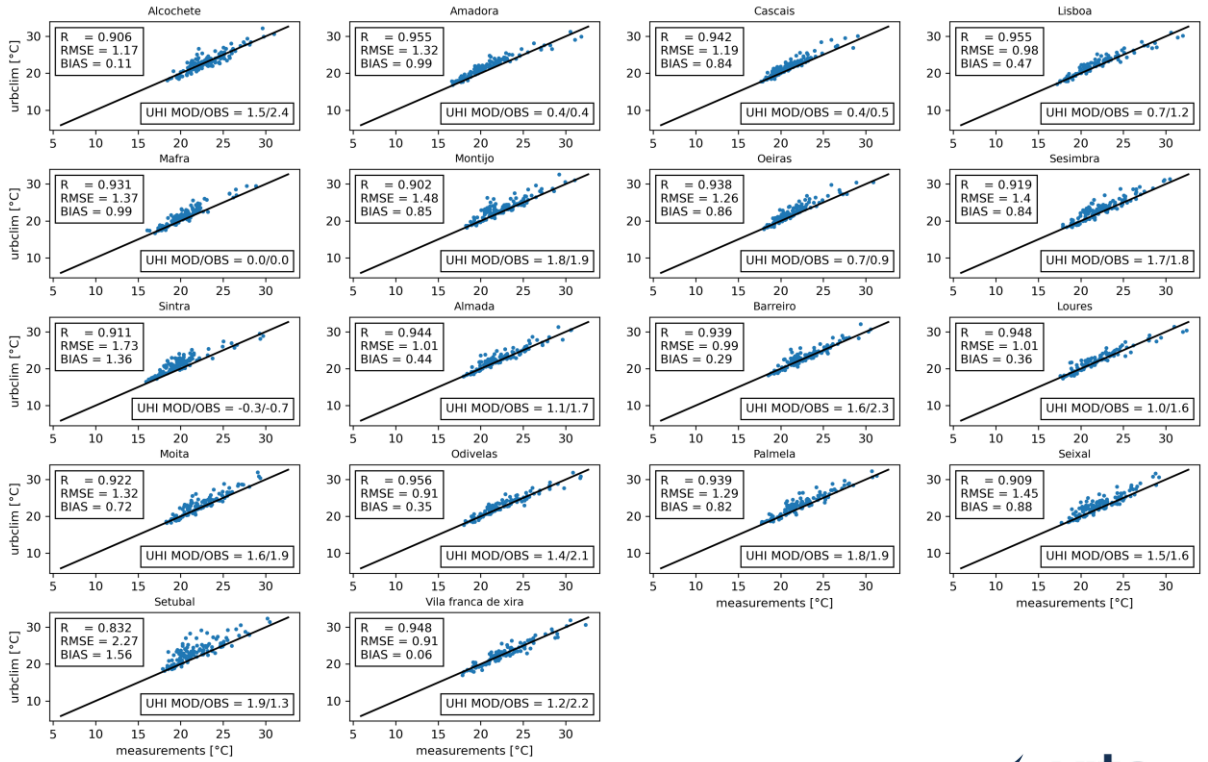
UrbClim validation

- UrbClim model results have been validated against 22 local measurement stations in Lisbon (18 of AML) for the summer of 2022



https://clima.aml.pt/page/publico



Comparison between observed and modelled daily average 2m air temp

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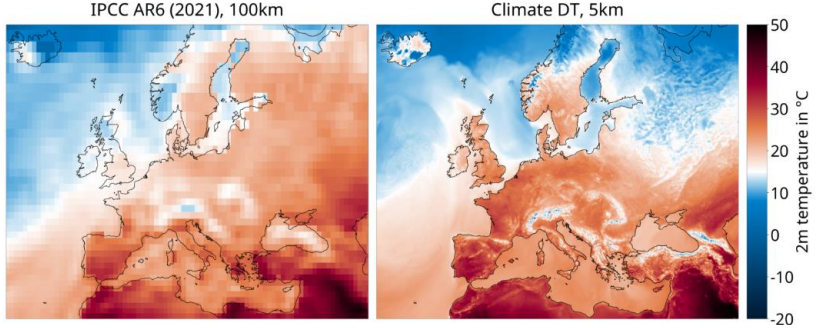
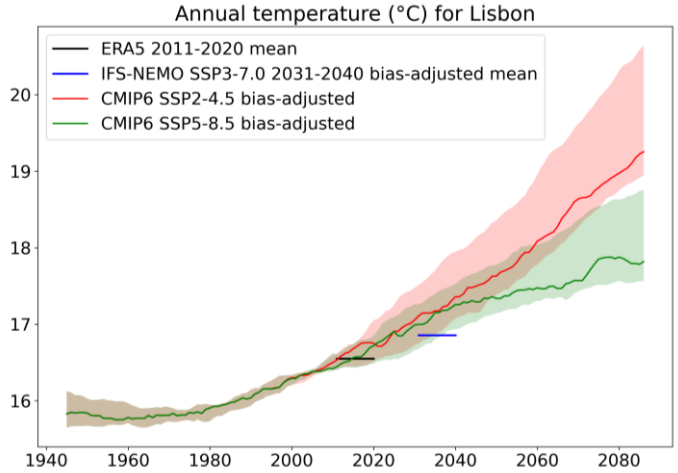
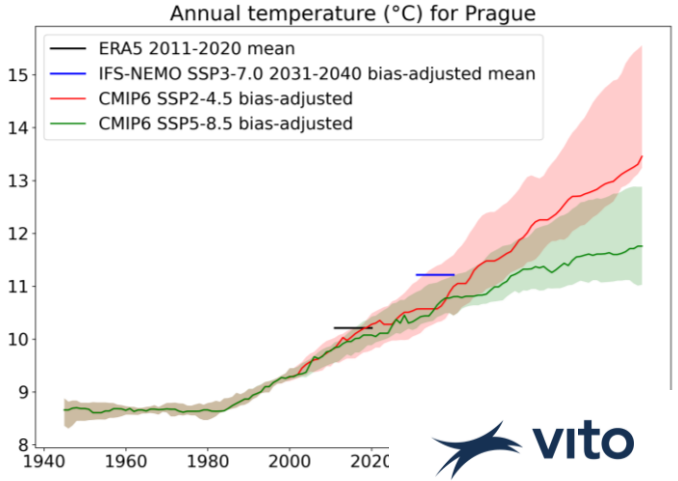
Climate DT projections

- The global climate models (3) of Destination Earth Climate DT run at an unprecedented spatial resolution of 5km
- Allow for flexible scenario calculations to study precise local impact
- For now only results for 1 model (IFS-NEMO) and 1 scenario (CMIP6 SSP3-7.0) available up to 2040
- For Lisbon: rather low impact compared to full CMIP6 ensemble
- For Prague: rather high impact compared to full CMIP6 ensemble



https://destine.ecmwf.int/news/climate-change-adaptation-digital-twin-a-window-to-the-future-of-our-planet





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Adaptation measures

- The impact of 5 ambitious climate adaptation scenarios has been calculated
- Allowing to assess the maximal effect you can obtain with these types of measures and compare between them
- The measures are focused on the urban areas in the region and applied everywhere in an automated manner

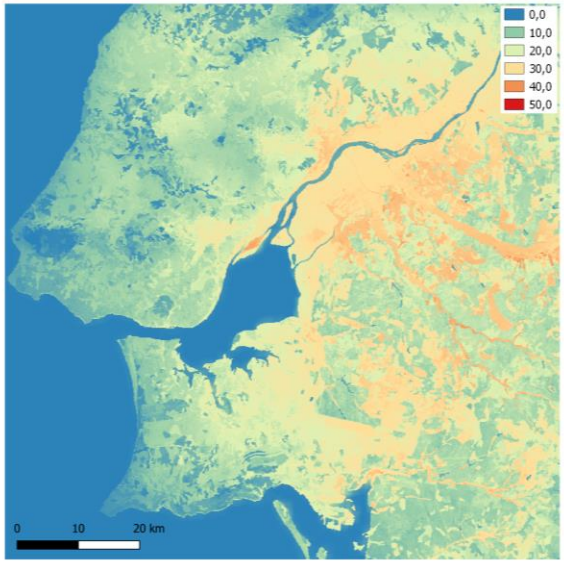
  => Previous results have shown that only the wide-spread application of measures is effective to reduce the overall urban heat stress in a city

1. Green roofs: all the roofs in the city are converted to intensive green roofs
2. Light-colored materials: the albedo of all build-up areas is changed to 0.3 (realistic white)
3. Soil unsealing: 50% of all non-building urban areas are unsealed
4. Urban trees: 50% of all non-building urban areas are under tree crown cover
5. Combination of all of these: maximum impact scenario

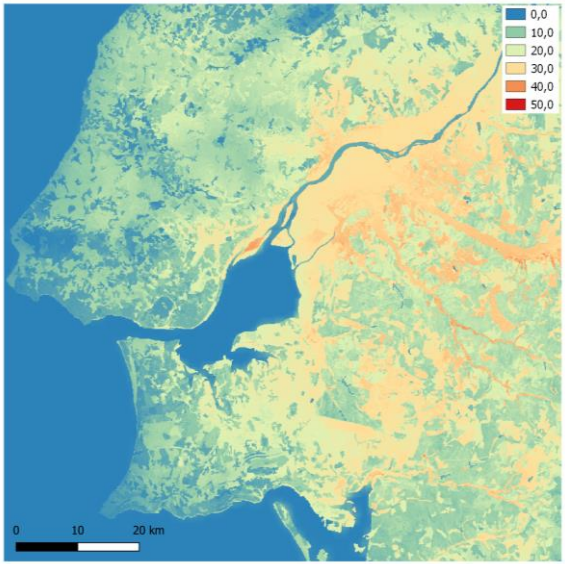
Urban Heat: Result maps

- The number of lost working hours is based on ISO 7243: Ergonomics of the thermal environment — Assessment of heat stress using the WBGT index (https://www.iso.org/standard/67188.html). They are calculated for intense, moderate and light manual work

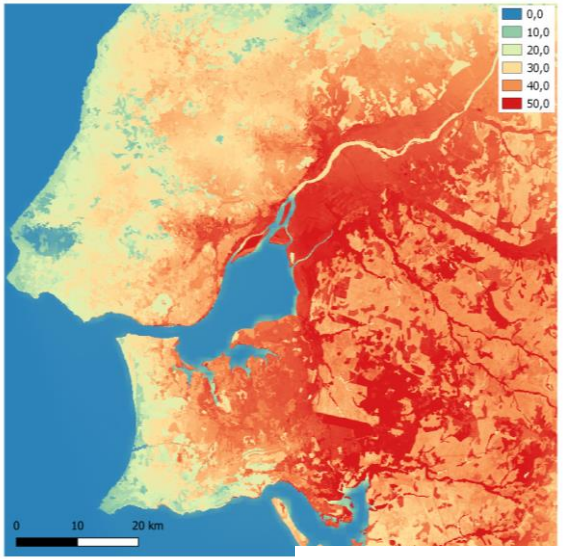
Average number lost working hours for intense manual work during the summer months. Source: VITO.



ERA5 2011-2020 Reference



ERA5 2011-2020 MAX scenario



IFS-NEMO SSP3

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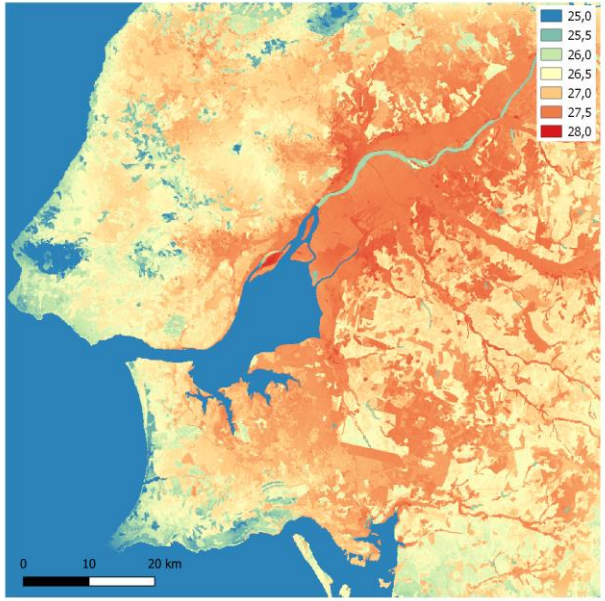
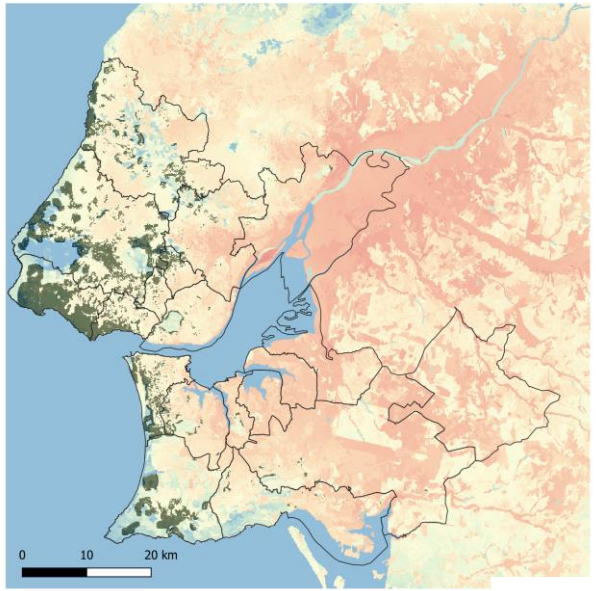
Urban Heat: Result maps

- Cool area identification: based on daily maximum WBGT maps during heat wave days, the non-water areas that are below a threshold value (1.0°C below the spatial P90 value and less than 300m from an urban grid cell) are selected. The 1.0°C limit is taken as it is a very significant reduction of the WBGT, which can only be obtained in grid cells with a large tree cover. 300m is considered a doable walking distance for most people.



Average daily maximum WBGT during heatwave days [°C]. Source: VITO.



Identified cool areas. Source: V

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Urban Heat: Results for Prague - overview

Impact of climate change

Prague city area - annual average values (urban areas only)			
Heat stress indicators	**Reference**	**2031-2040 SSP3-7.0 IFS-NEMO**	
			Relative change [%]
Urban Heat Island [°C]	1,29	1,29	0,00
Health Heat Wave Days	8,93	8,55	-4,27
Tropical Nights	16,18	31,44	94,36
Days with UTCI > 26°C	100,14	104,11	3,96
Days with WBGT > 25°C	5,69	21,51	277,71
Lost Working Hours for intense manual work	3,87	49,14	1170,72
Heat-related mortality	123,67	211,70	71,19

Impact of adaptation measures

Prague city area - 2011-2020 annual average values (urban areas only)							
Heat stress indicators		**Adaptation scenarios**					
	Reference	**Green Roofs**	**Light-colored materials**	**Soil unsealing**	**Urban Trees**	**Combination of all**	**Max impact [%]**
Urban Heat Island [°C]	1,29	0,98	1,19	0,94	1,30	0,71	-44,96
Health Heat Wave Days	8,93	8,25	8,41	8,18	9,07	7,76	-13,11
Tropical Nights	16,18	11,37	15,44	11,81	16,11	8,11	-49,84
Days with UTCI > 26°C	100,14	80,74	101,13	94,16	88,63	72,22	-27,88
Days with WBGT > 25°C	5,69	4,58	5,39	5,56	4,92	4,31	-24,31
Lost Working Hours for intense manual work	3,87	1,94	3,37	3,61	2,77	1,4	
Heat-related mortality	123,67	107,40	116,78	107,21	123,53	95,	

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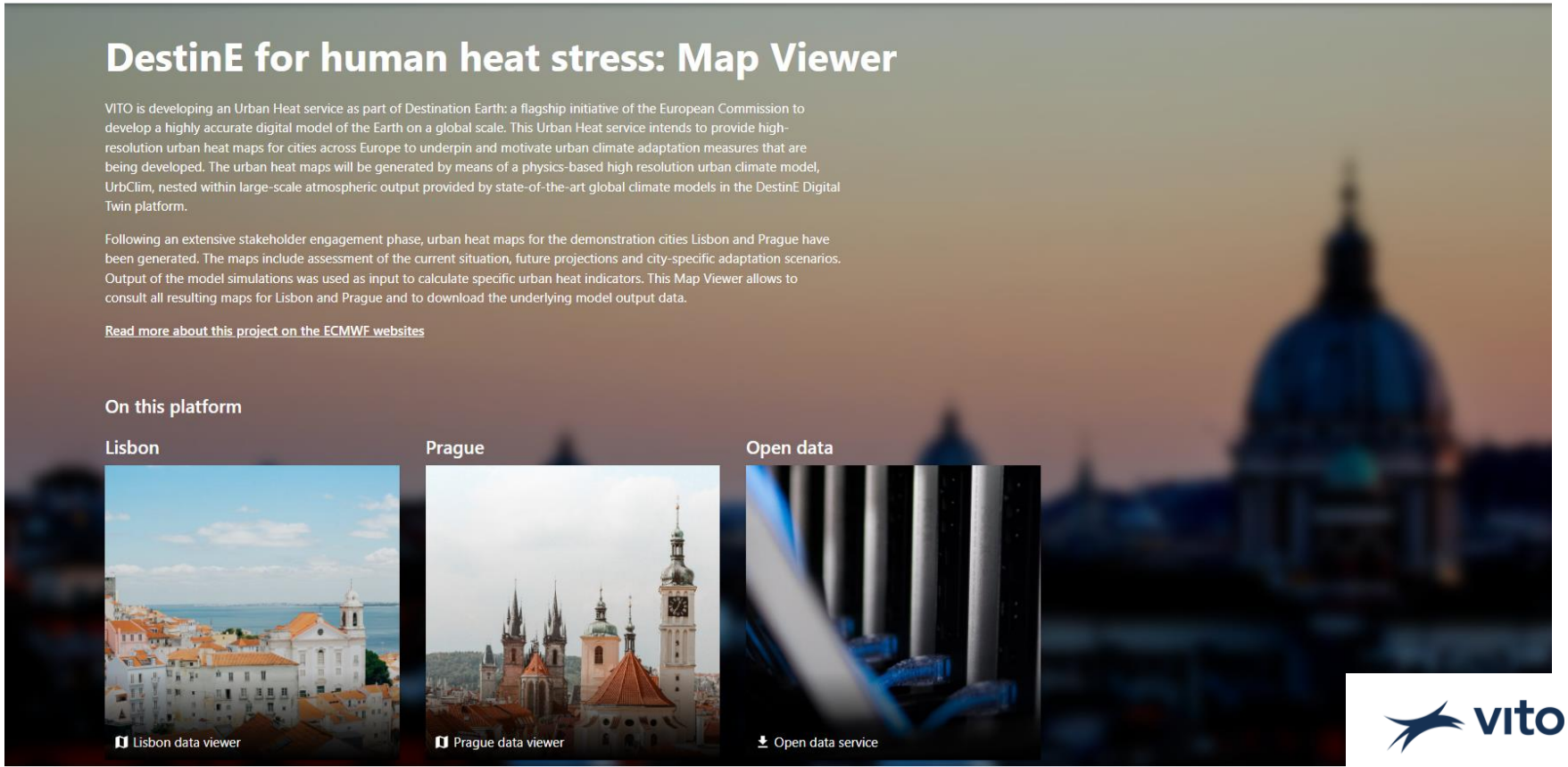
Urban Heat: Web viewer

https://destinationearth.marvintest.vito.be/



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