High PV penetration in urban areas: a pilot from the e-shape H2020 project

Rodrigo Amaro e Silva
MINES ParisTech / ARMINES

PEARL PV workshop, 24th September 2021

The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Programme

- PV modelling in urban environments
- e-shape H2020 project
- Pilot on

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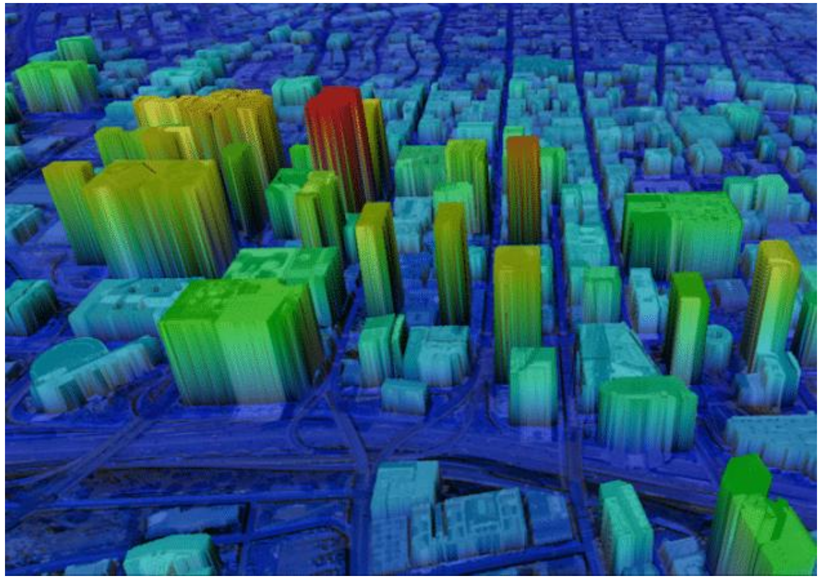
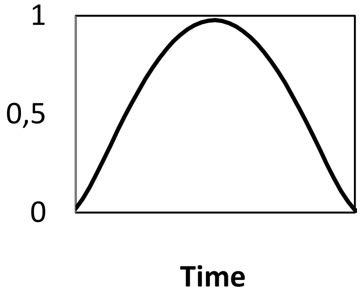
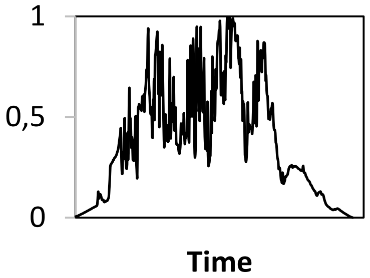
PV modelling in urban environments



Digital Surface Model (DSM)

+





Solar resource timeseries

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Solar Cadaster: high resolution (metric) urban solar mapping

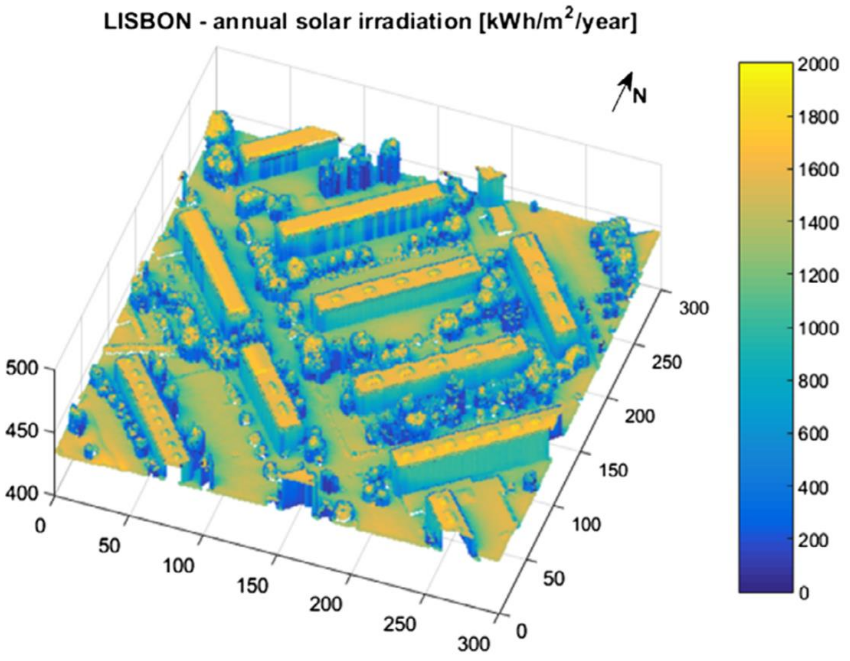

Figure 4. Total annual solar irradiation on rooftops and facades in the DSM, for the Lisbon case study.

A traditional output is a solar cadaster

Brito et al. (2021) Characteristic Declination—A Useful Concept for Accelerating 3D Solar Potential Calculations

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Solar Cadaster: high resolution (metric) urban solar mapping

Solar Cadasters enable to:

- Analyse the PV potential of urban surfaces
- Inform public or private decision-makers and investors

The modularity and flexibility of PV makes it very interesting for urban areas

- Exploit building rooftop and façades, parking shades, etc.

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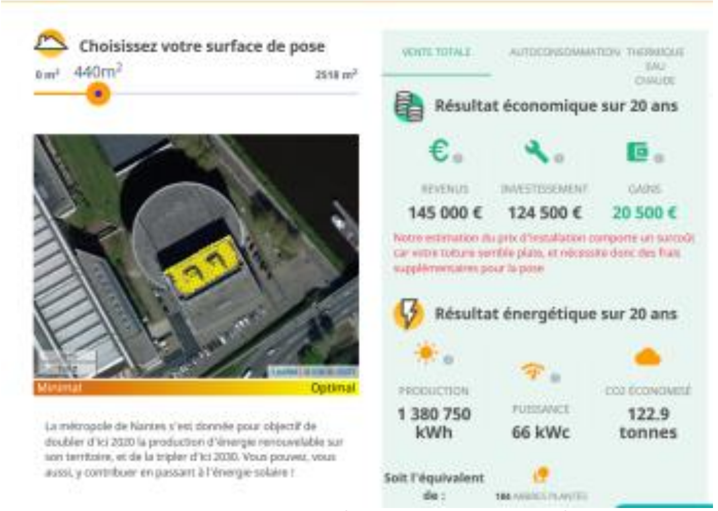
Solar Cadaster: high resolution (metric) urban solar mapping

<u>In Sun We Trust</u> is providing free, accurate and easy-to-use tool for the **general public** to assess solar potential of rooftop PV systems



nantes-metropole.insunwetrust.solar

With the support of:

- The French national mapping agency (IGN)
- MINES ParisTech
- Transvalor Innovation - SoDa

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“Business as usual” for solar cadasters

- High resolution (space x time) data...
  - Huge **data storage needs**

- Demands **compromise**
  - Coarser temporal resolution (annual yield)
  - Smaller area of coverage

- In any case, we end up with **a very limited/static dataset**
  - Heavy computations
  - Too much data

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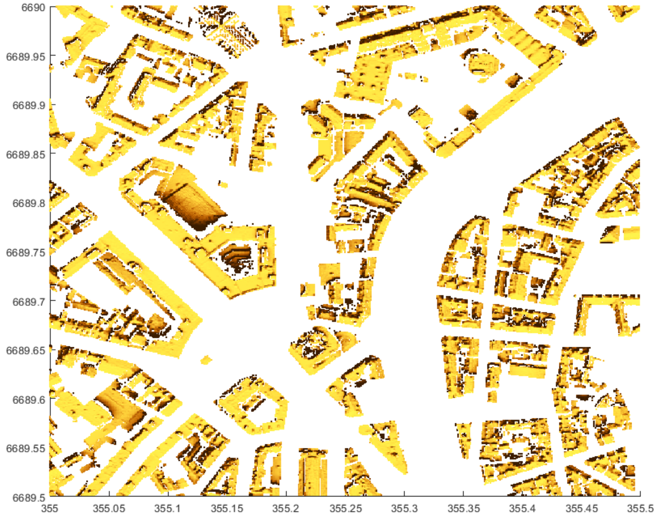
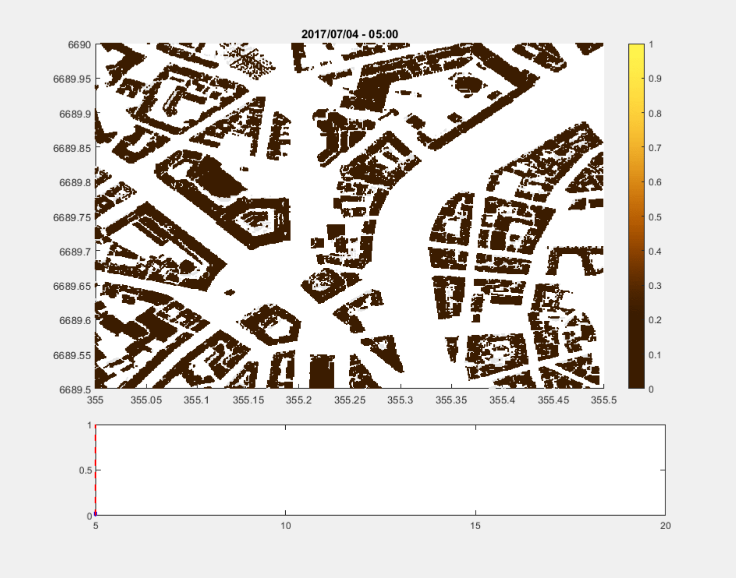
That’s where e-shape comes into play

“static” Yearly irradiation on tilted plans (1-m res.)



Near on-the-fly cloud-baed computation of intra-day irradiation on tilted plans (1-m res.)



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e-shape

EuroGEO Showcases: Applications Powered by Europe

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e-shape - EuroGEO Showcases Applications Powered by Europe

- 15M€, 60 partners, 7 showcases, **32 pilots**
- **4 years** grant (2019-2023)
- **ARMINES** (France) coordinator – e-shape.eu

agriculture | health | renewable energy | ecosystem | water | disaster | climate

- Promoting **users' uptake** of European Earth Observation resources
- Building on **Copernicus and GEOSS** through the development of **co-design pilots**
- Built on a **user-centric** approach to deliver **economic**, **social** and **policy value** to European citizens.

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Pilots workflow

Showcases	Number of Pilots
agriculture	6
health	3
renewable energy	4
ecosystem	3
water	7
disaster	4
climate	5

Support work-packages

- *Project Management*
- Co-design
- Implementation
- User Uptake
- Sustainability & Upscaling
- Communication
- Ethics

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Renewable Energy Showcase
Pilot #2: High PV penetration in urban area

- **Objective:** Develop GIS-flavor tools to support **high photovoltaic penetration** at urban scale by providing **EO based information**

- **Expected user community:** Urban planners, grid operators, aggregators for energy trading, researchers in Energy and citizens

- **Two parts of the pilot:**
  - **ARMINES' part : PV variability at urban scale (Pilot in Nantes)**
  - *DLR' part: EO-data for PV integration in the urban energy system (Pilot in Oldenburg)*

- **Partners:**

ARMINES MINES ParisTech PSL TRANSVALOR SoDa Solar radiation Data DLR

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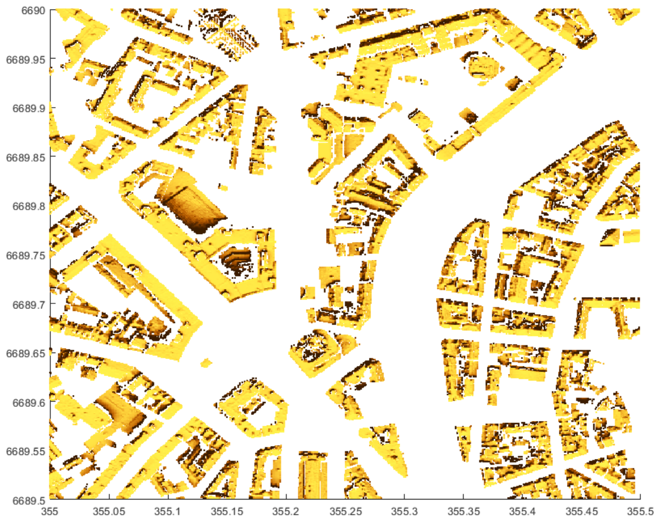
From solar cadaster to urban-scale solar variability

As PV penetration grows, more refined information is needed

- Shifting from a PV potential-only to a broader perspective

“static” Yearly irradiation on tilted plans (1-m res.)



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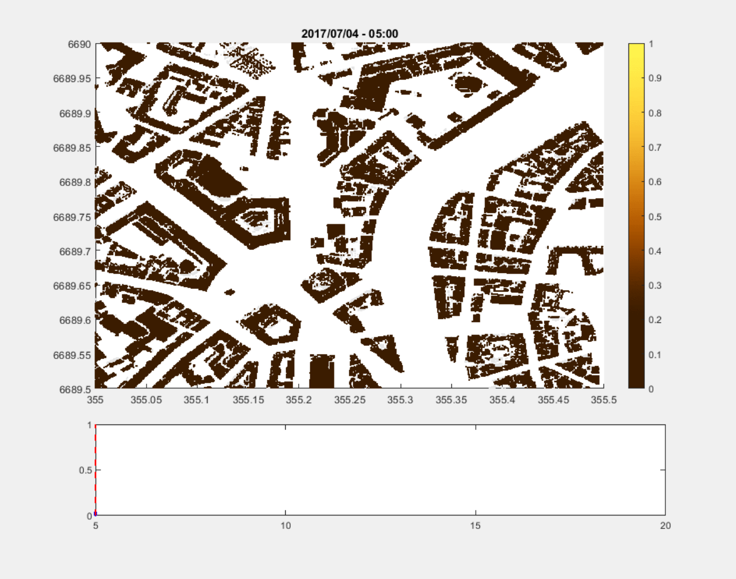

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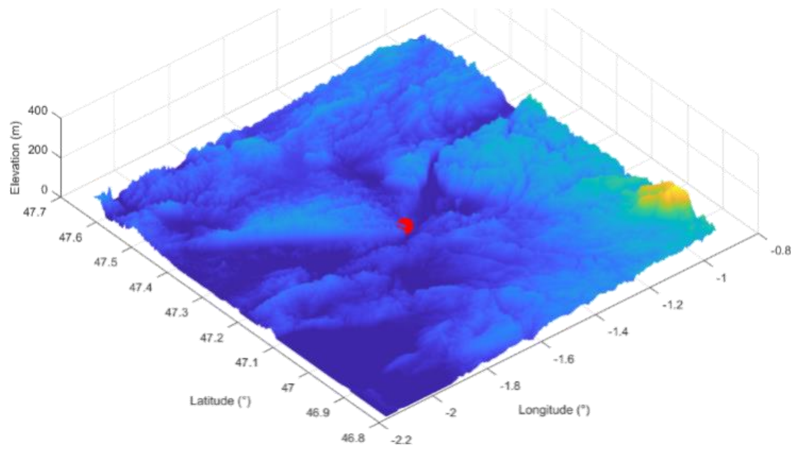
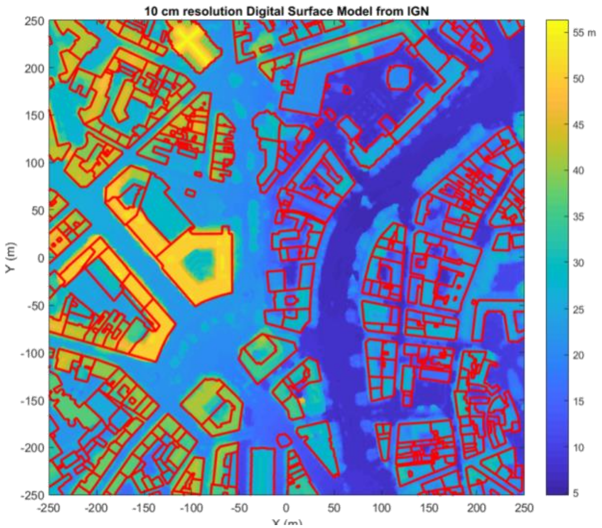
Earth Observation (EO) data – surface modelling



DTM
decametric digital terrain model
(e.g. SRTM, ASTER)



DTM + map of buildings
high-resol. digital surface model
(IGN - BDTOPO©)

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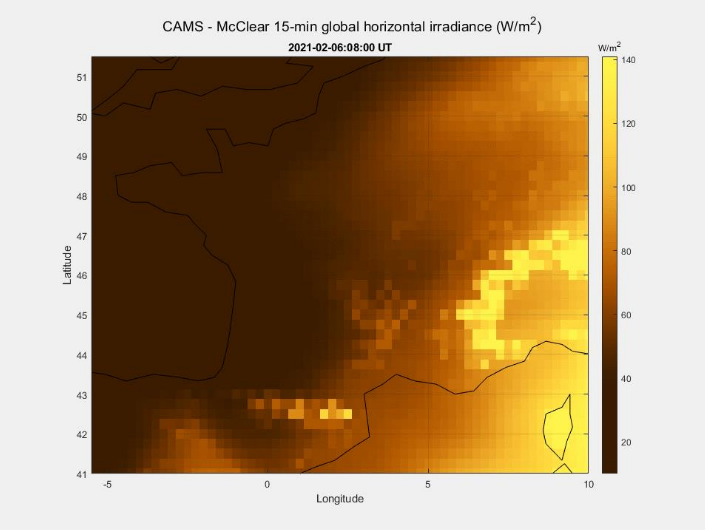
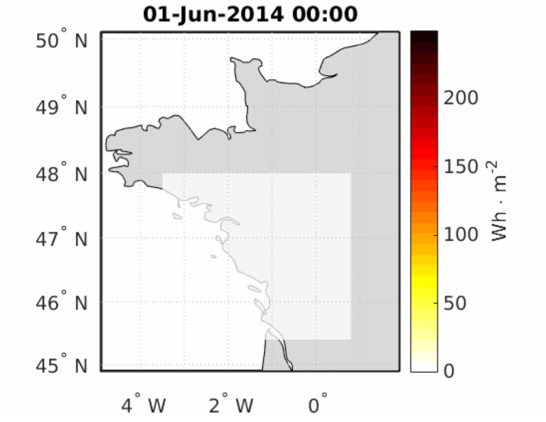
Earth Observation (EO) data – solar irradiance modelling





Clear-sky irradiance
aerosols, water vapour
McClear (CAMS)

All-sky irradiance
clouds
CAMS-Rad / HelioClim3

Ground-level irradiance
calibration
In-situ measurments

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Data and Information Access Services (DIAS)

- **DIAS WEkEO**: reference service from the EU Copernicus for environmental data, virtual processing environments and skilled user support.

- **“Back-office”**: providing cloud processing requested on-the-fly through asynchronous OGC Web Processing Services (WPS)

- **“Front-Office”**: hosting a Jupyter Hub with Jupyter Notebooks exemplifying in Python different use-cases.

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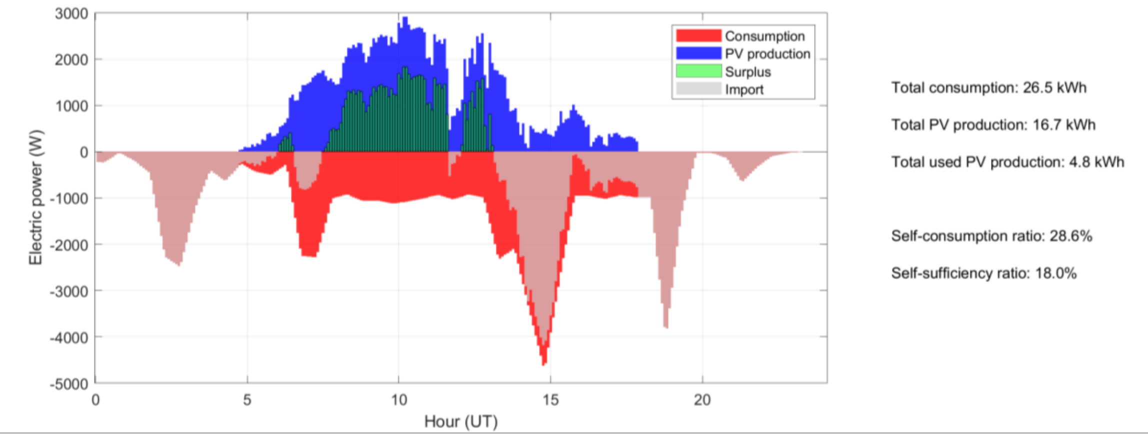
Use case #1: PV sizing for self-consumption

- In Sun We Trust

1-h electric consumption from the customers



Total consumption: 26.5 kWh

Total PV production: 16.7 kWh

Total used PV production: 4.8 kWh

Self-consumption ratio: 28.6%

Self-sufficiency ratio: 18.0%

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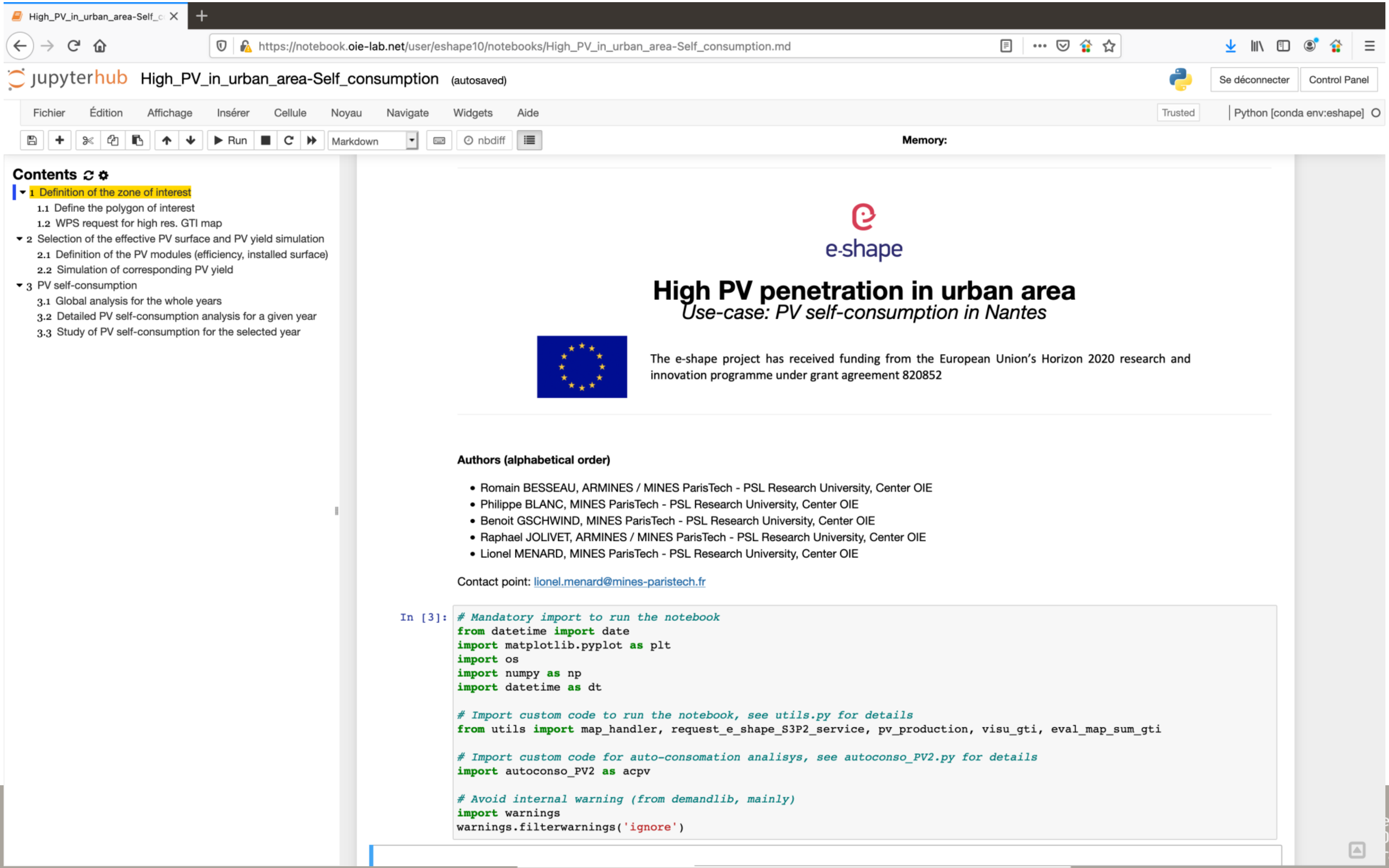
Available pilot on Jupyter Notebook



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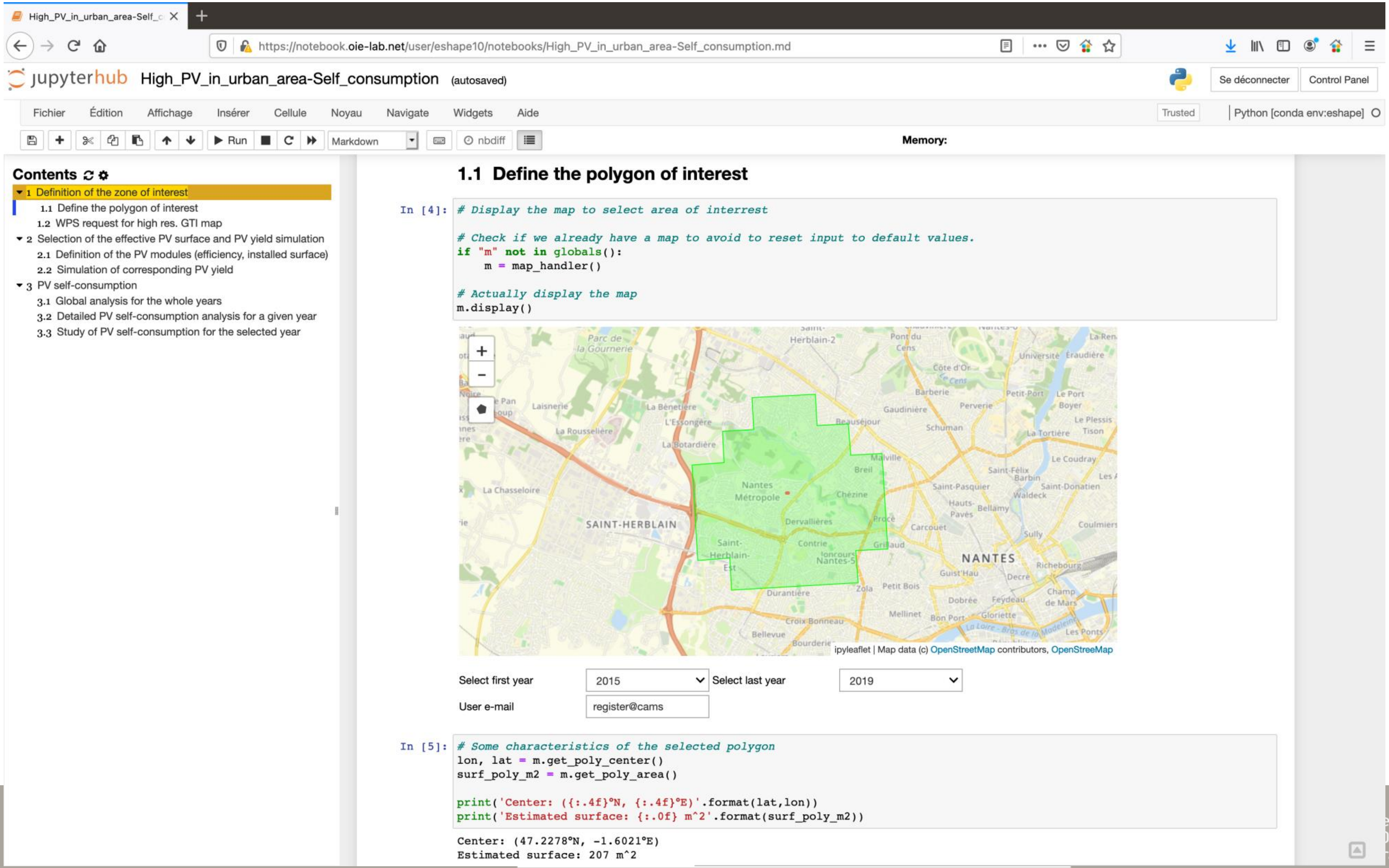

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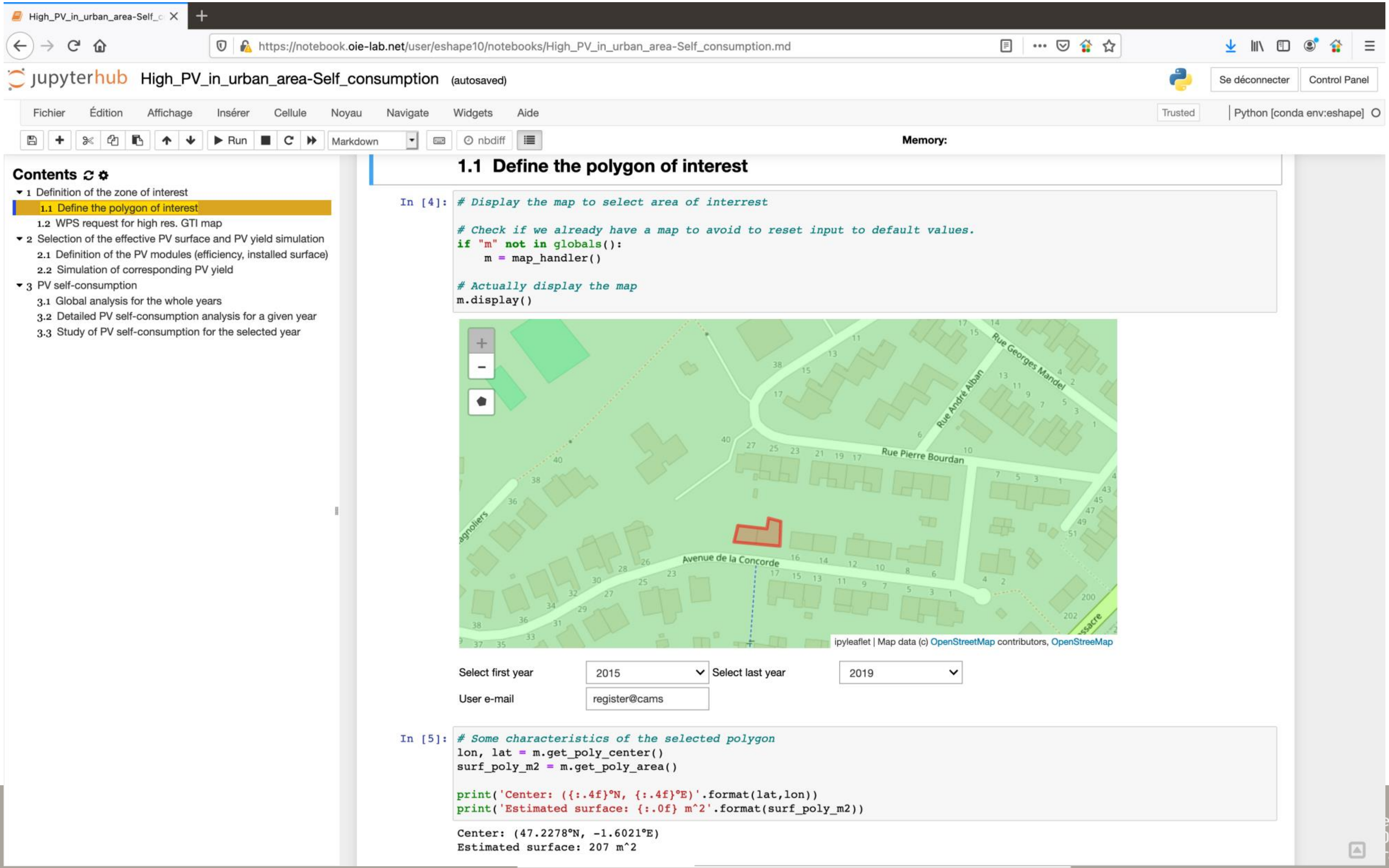

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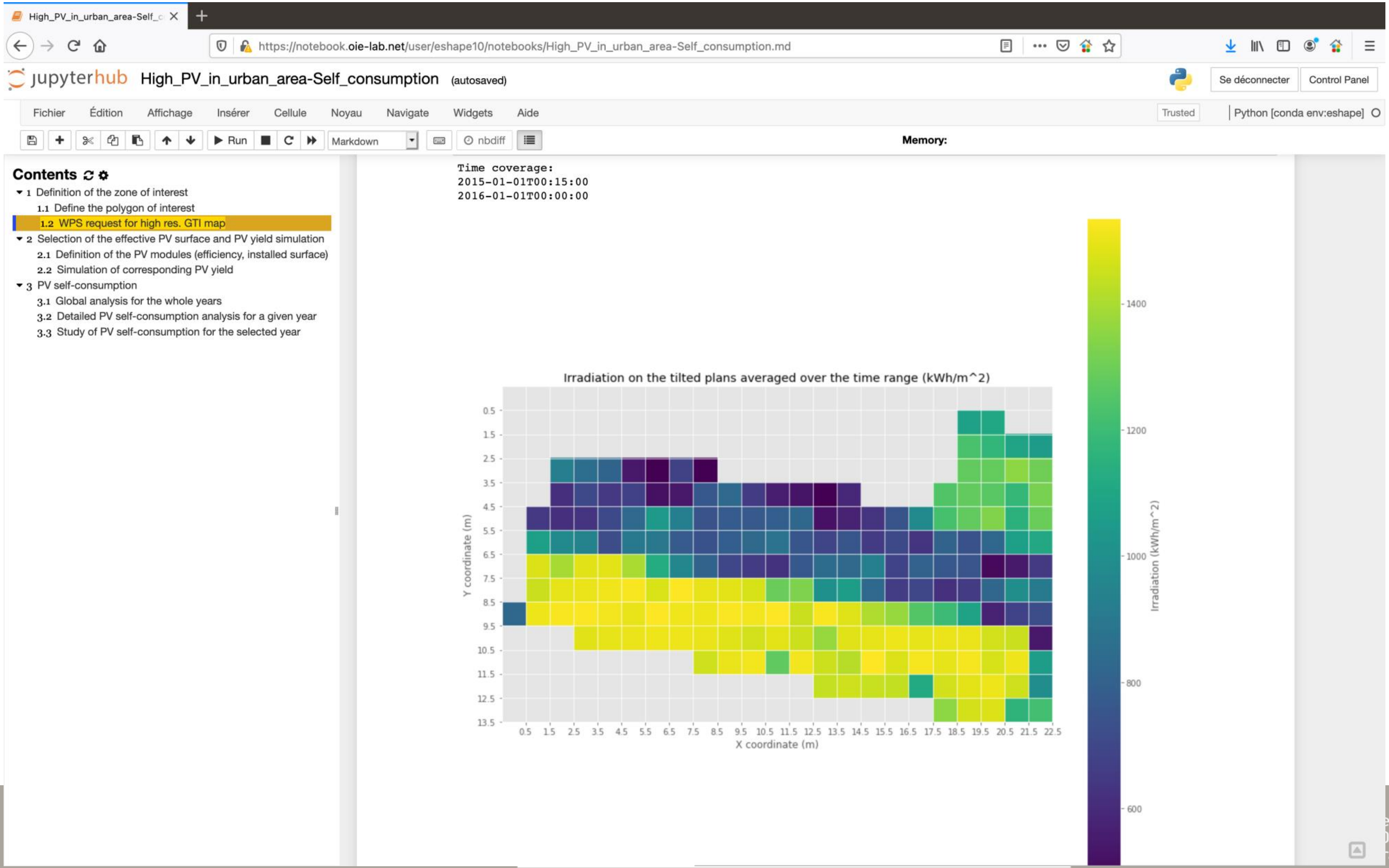

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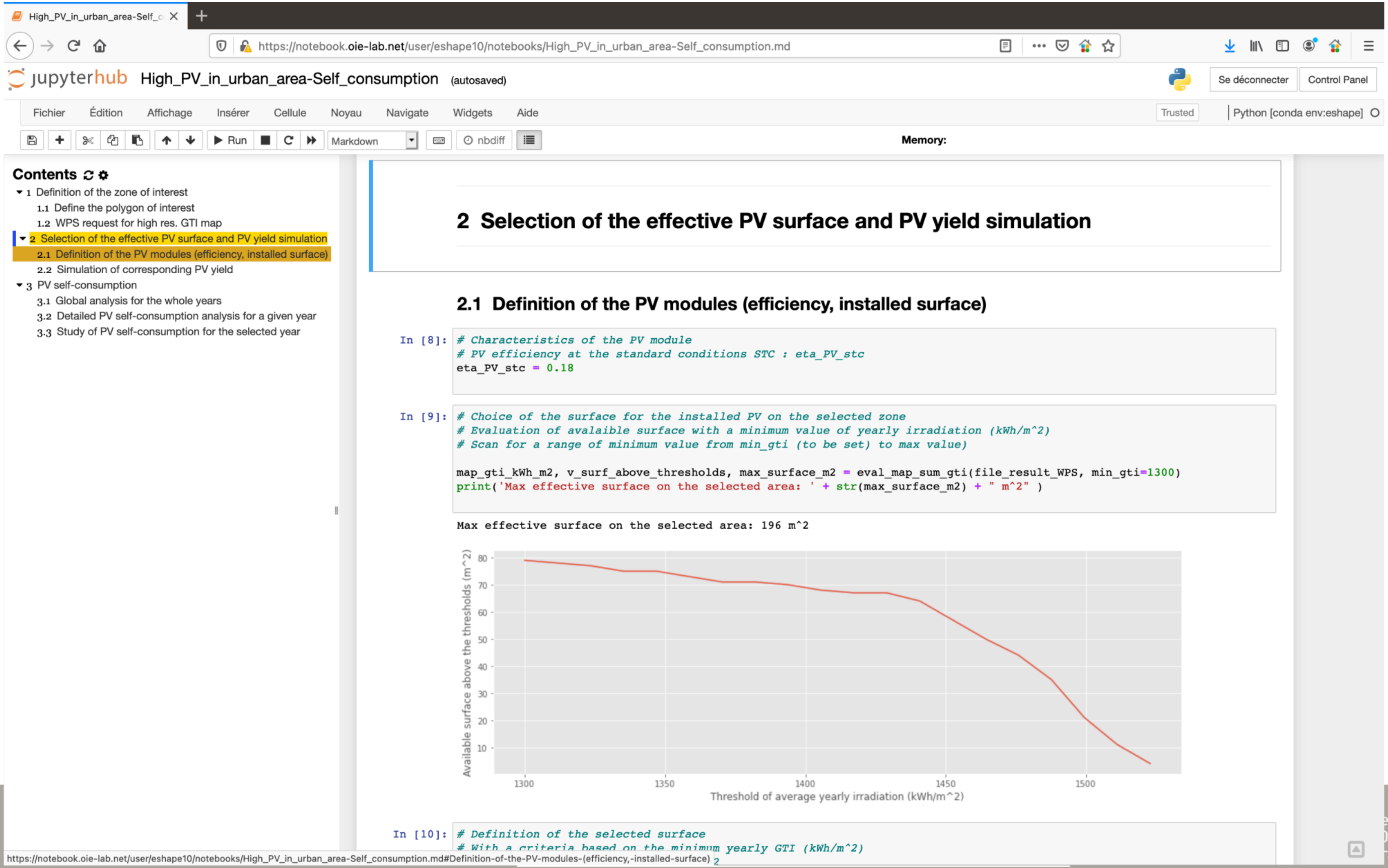

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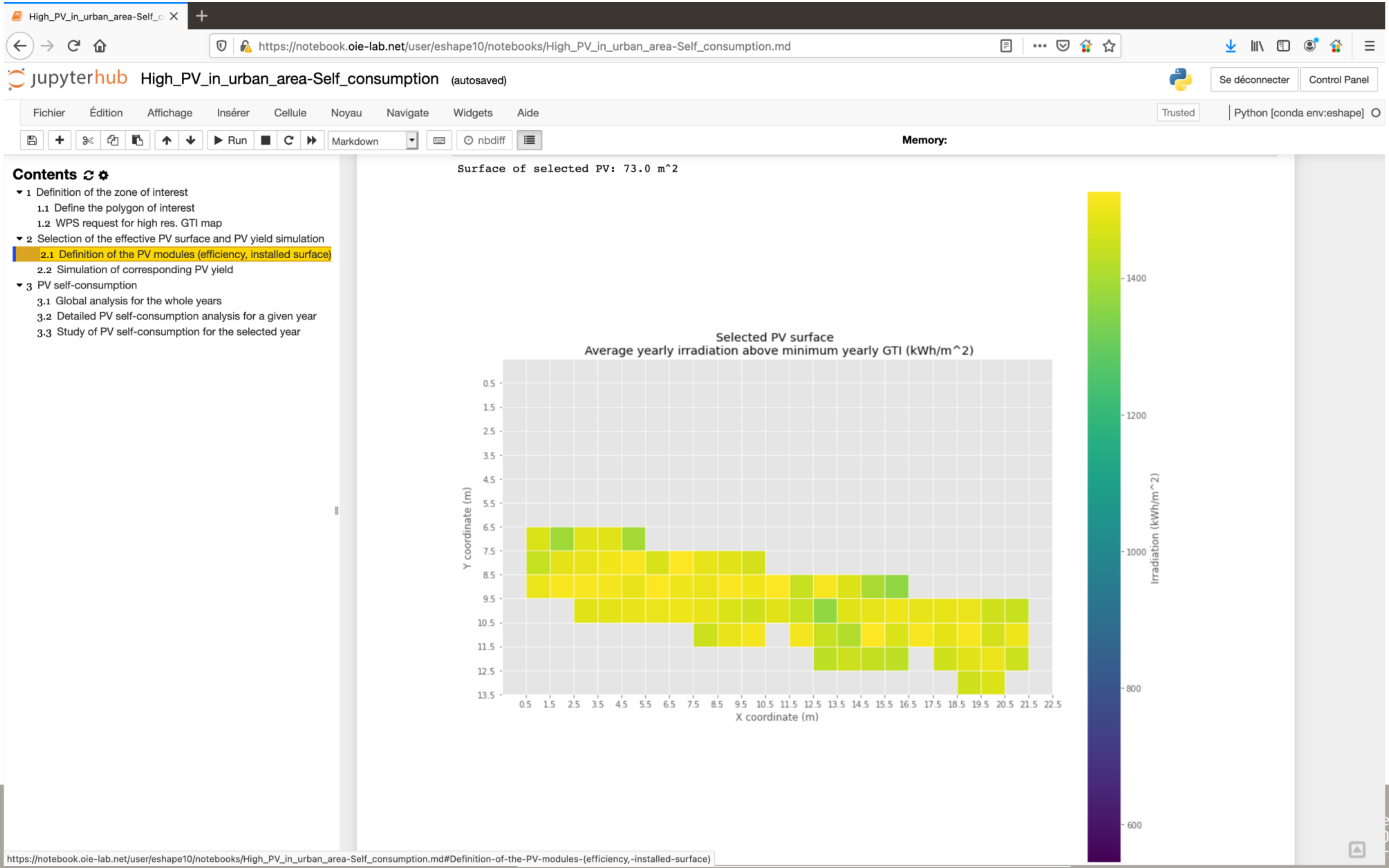

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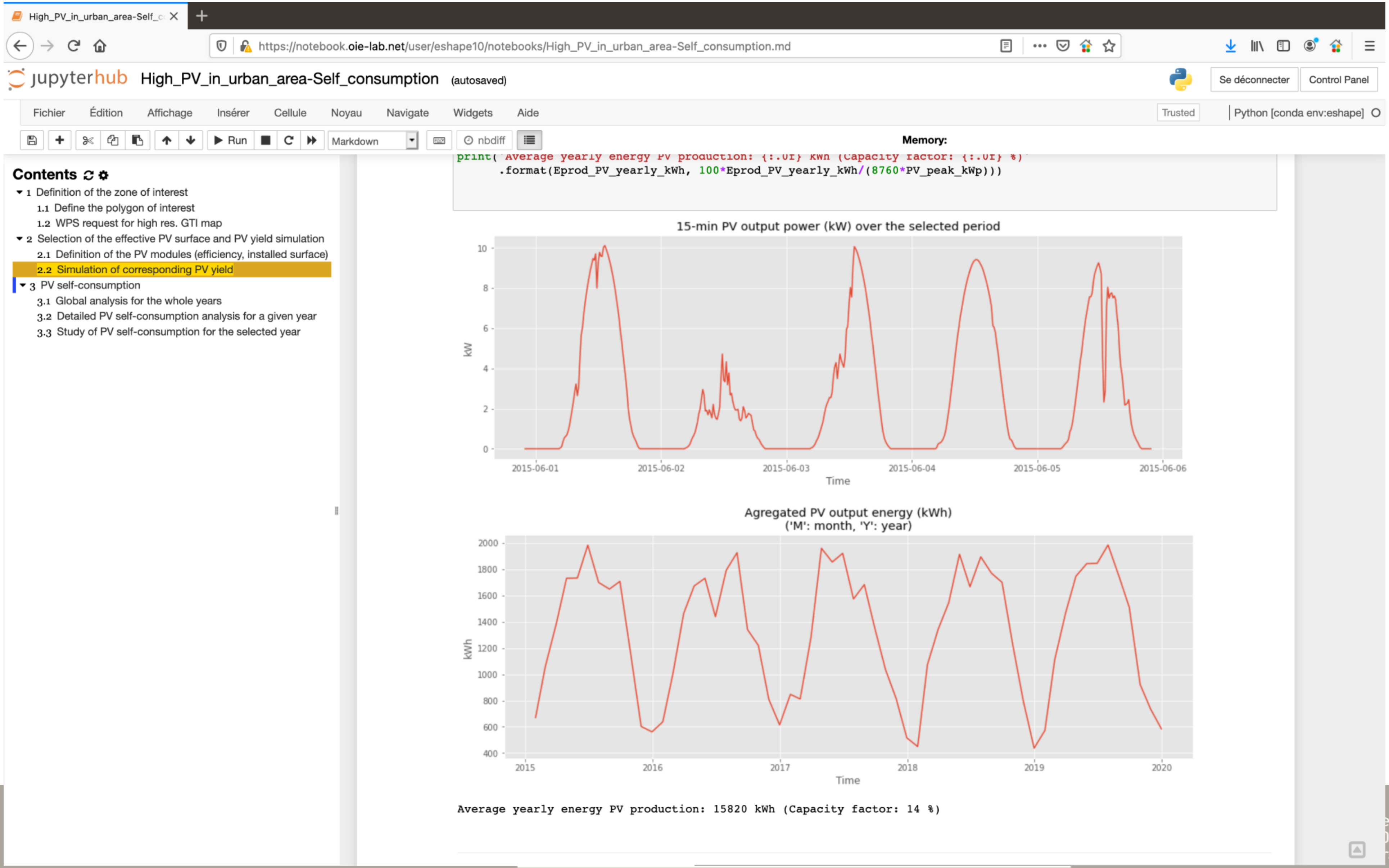

Available pilot on Jupyter Notebook

High_PV_in_urban_area-Self_c

https://notebook.oie-lab.net/user/eshape10/notebooks/High_PV_in_urban_area-Self_consumption.md

Liste de Lecture | CityGML | Connexions | Confluence | Copernicus | DIAS | Directory | Work In Progress | ERDDAP | e-shape | GeoNetwork 3 | GKH | Jupyter | NextGEOSS | STAC | THREDDS

jupyterhub High_PV_in_urban_area-Self_consumption (autosaved)

Se déconnecter | Control Panel

Fichier | Édition | Affichage | Insérer | Cellule | Noyau | Navigate | Widgets | Aide

Trusted | Python [conda env:eshape]

Run | Code | nbdiff | Memory:

Contents

3.1 Global analysis for the whole years

In [14]:

```
# Year per year PV self-consumption (simple) analysis

# Typical consumption profile

# 'h0':'Household',
# 'g0':'Commerce general',
# 'g1':'Commerce operating weekdays from8:00 h to 18:00h',
# 'g2':'Industry/commerce featuring strong topredominant consumption in the evening',
# 'g3':'Industry/commerce with continuousactivity',
# 'g4':'Shop/barber',
# 'g5':'Bakery',
# 'g6':'Weekend operation',
# 'l0':'Farms general',
# 'l1':'Dairy farms',
# 'l2':'Other farms'}

Consumption_prfl = 'h0'

# Average power of consumption (kW)
Pconso_avg_kW = 5

Econso_yearly_kWh = Pconso_avg_kW*8760

print('Average power consumption: {:.2f} kW'.format(Pconso_avg_kW))
print('Corresponding yearly energy consumption: {:.2f} kWh'.format(Econso_yearly_kWh))

tab_yyyy = np.zeros((nb_years,1), dtype = 'int')
tab_Self_consumption_ratio = np.zeros((nb_years,1))
tab_Self_sufficiency_ratio = np.zeros((nb_years,1))

print('Computation for year per year analysis:')
for k in range(nb_years):
    tab_yyyy[k,0] = yyyy0 + k
    print('\t- Year {:04d}/{:04d}'.format(tab_yyyy[k,0], yyyy1))
    Consum = acpv.conso_demandlib(name = Prod.name,
                                  year = tab_yyyy[k,0],
                                  profil = Consumption_prfl,
                                  annual_conso = Pconso_avg_kW*8760,
                                  weather = Prod.build_weather(),
                                  timezone = Prod.timezone)
    Consum.calculate_conso()
    SC = acpv.site_AC(Prod = Prod, Conso = Consum)
    stat_SC = SC.calculate_autoconso_simple()

    tab_Self_consumption_ratio[k,0] = 100.0 * stat_SC['kWh'].PV_self_consumed  / stat_SC['kWh'].Prod_PV
    tab_Self_sufficiency_ratio[k,0] = 100.0 * stat_SC['kWh'].PV_self_consumed / stat_SC['kWh'].Consum_elec
```

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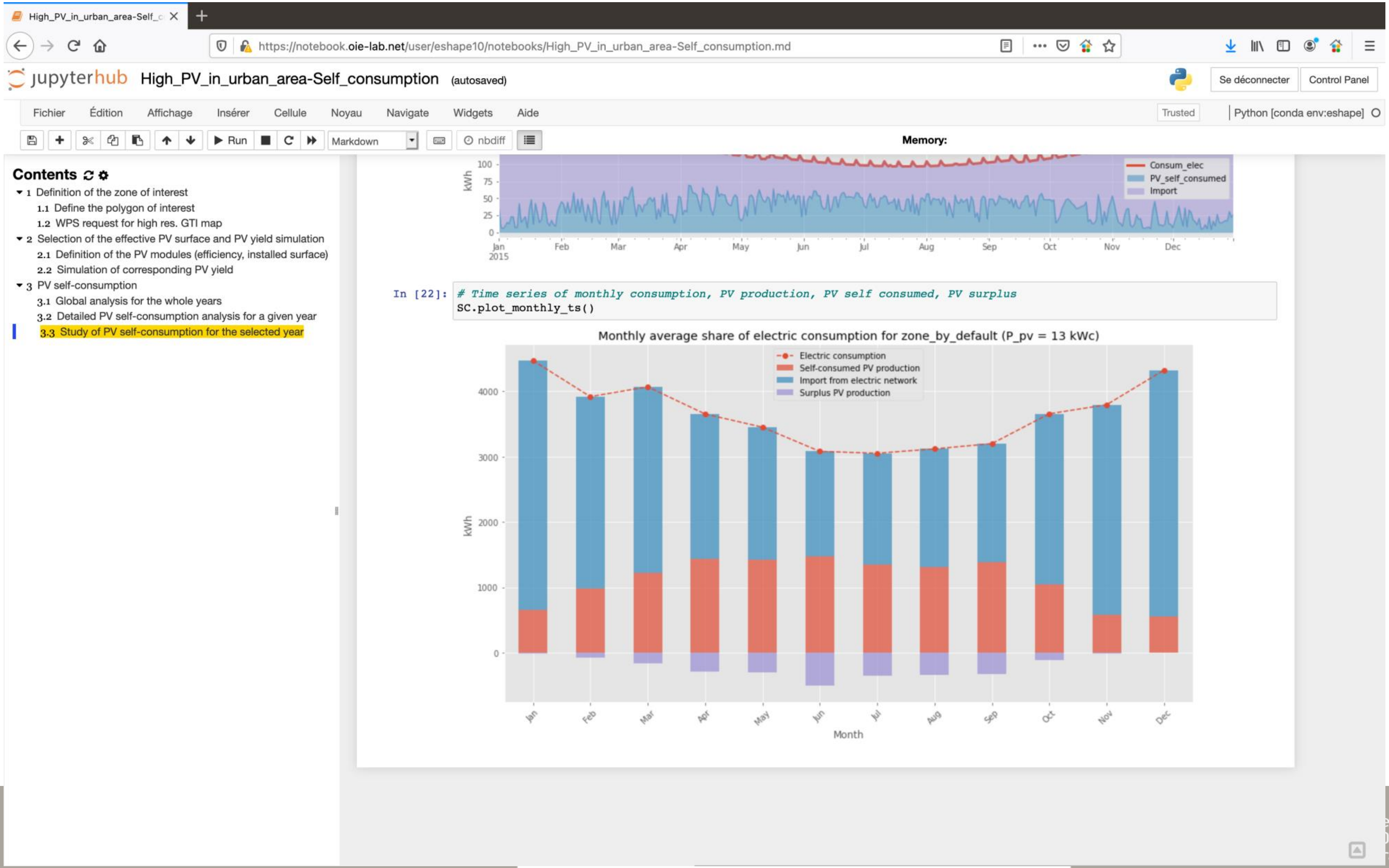
Available pilot on Jupyter Notebook



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Available pilot on Jupyter Notebook

- Hands-on session recording - Youtube: https://www.youtube.com/watch?v=Sj9eMoLFi0g

- To get an account to test the pilot: lionel.menard@mines-paristech.fr

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Use case #2: PV injection in distribution feeders

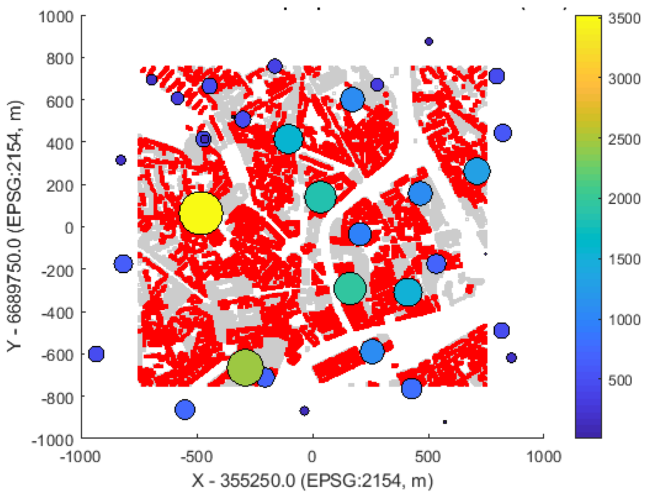
- Simulating different PV penetration scenarios (for DSO, e.g. ENEDIS)

Example: urban area of of 1.5 km x 1.5 km

20 % PV penetration:

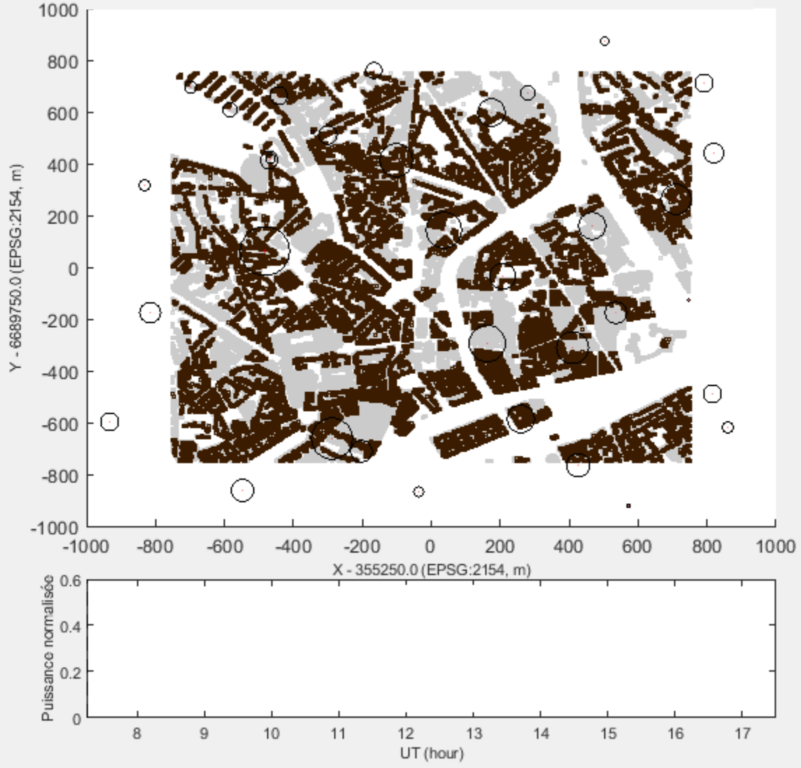
35 related feeders of ENEDIS (DSO)

14 ha of PV rooftop systems (~ 20+ MWp)



Nameplate PV power injected in the source points

Temporal evolution of instantaneous PV power potentially injected within a day



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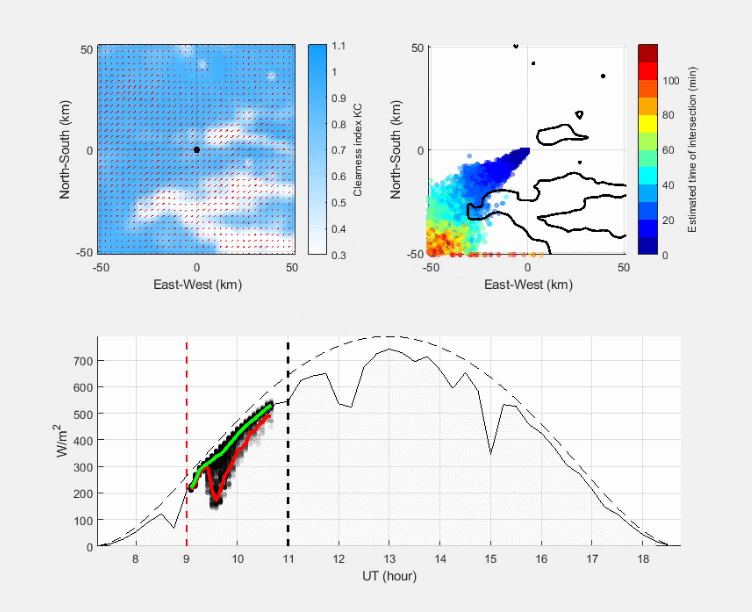
Use case #3: PV now & short-term forecasting

- Relevant for energy trading with portfolio of PV rooftop systems
  (e.g. Urban Solar Energy ?) Urban Solar energy

- Use of Cloud Motion Vector (CMV) from two consecutive satellite images
  + CAMS aerosol / water vapor forecasting (CAMS McClear)
  + 3D shadowing effects from DSM



Carrière et al. (2021) A New Approach for Satellite-Based Probabilistic Solar Forecasting with Cloud Motion Vectors

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Use case #3: PV nowcasting & short-term forecasting

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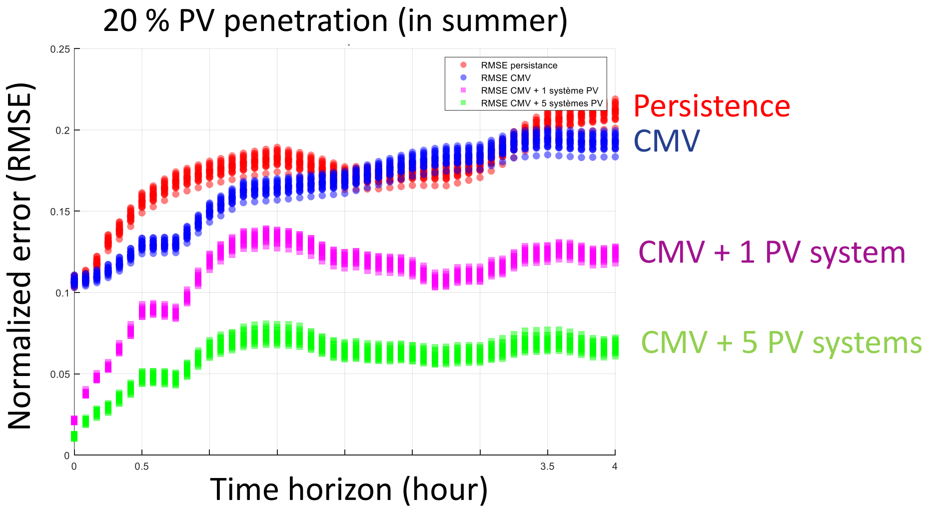

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www.oie.mines-paristech.fr

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EXTRA SLIDES

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Data & Data and Information Access Services (DIAS)

- **Data used:**
    - **CAMS Radiation Service** (SoDA) to retrieve **all-sky irradiation**, aerosols, water vapor – External request via **OGC WPS** (Free registration mandatory)
    - Satellite-based decametric **DEM** (**SRTM**) – Internal (External possible)
    - **Digital Surface Model** (10-25 cm resolution) (IGN) – Internal (External possible)
    - **Building footprints** (BDTOPO© from IGN) - Internal
    - **MERRA2 temperature** re-analysis – Internal (External possible ERA5)
    - **Consumption** data (**Models** - Internal)

- **Processes:**
    - *2 "Back-office VM"* 4xlarge (RAM:128GB CPUs: 32 Disk: 512GB)
        - Sandbox and **Production**: Providing **OGC WPS cloud processing**
    - *1 "Front-Office VM"* xlarge (RAM: 64GB CPUs: 8 Disk: 256GB)
        - Hosting a **Jupyter Hub** with **Jupyter Notebooks** developed in **Python**
            - **GIS-flavor interface** (OSM - ipLeaflet, Free AOI, forms)
            - **NetCDF-CF output data** for exploitation and representation

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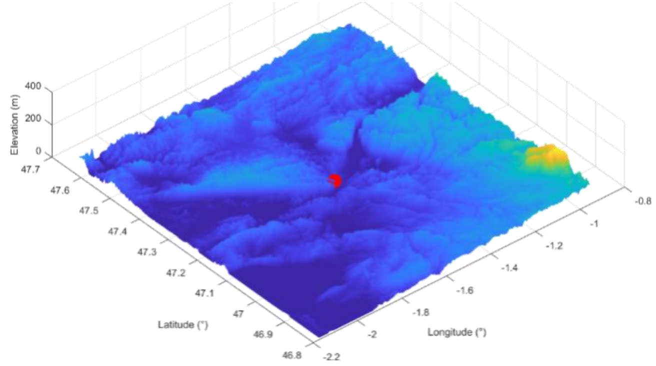
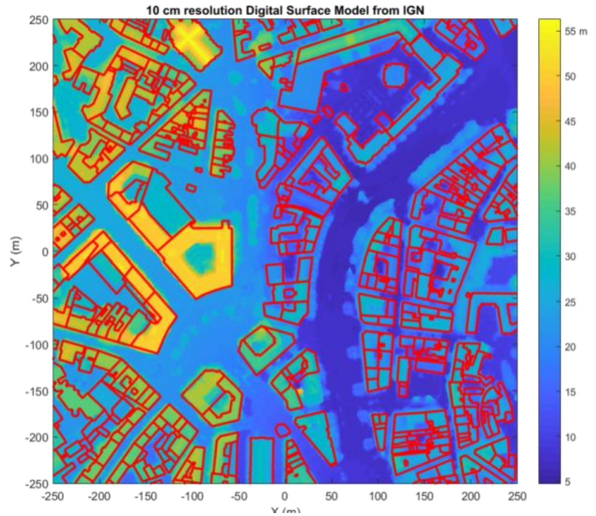
Earth Observation (EO) data for shadow modelling

- A **decametric digital terrain model (DTM)** to describe the **orographic shadow effects** (e.g. SRTM, ASTER)



- A high-accuracy 10 cm **digital surface model (DSM)** to provide **3D description of buildings, vegetation and superstructures** (IGN, using aerial images correlation)



- A high-accuracy **map of buildings** to provide **location and contours of corresponding roofs** (IGN - BDTOPO©)

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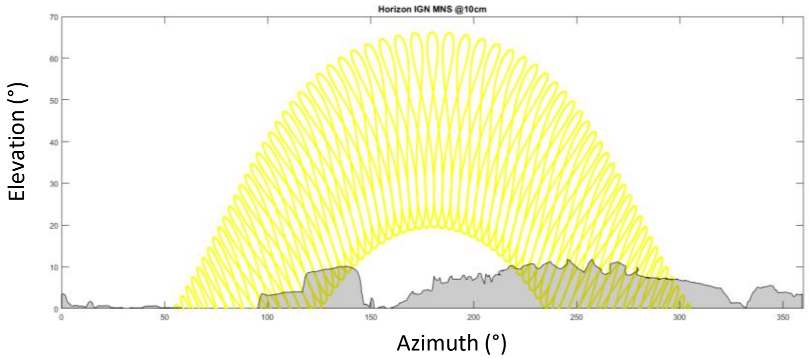

Derived horizon (gray filled polygon) compared to the annual Sun path (yellow dots)

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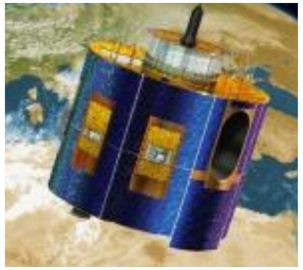
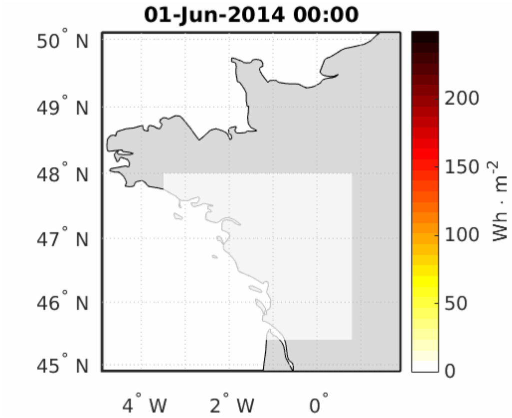
Earth Observation (EO) data for clear-sky irradiance

- Satellite-based all-sky solar data HelioClim-3 / CAMS Rad (3 km, 15 min, 2004-, 15+ years)

Atmosphere Monitoring Service
atmosphere.copernicus.eu

- Based on images from SEVIRI spaceborne by Meteosat Second Generation (MSG)





- At least one year of in-situ pyranometric measurements for local calibration

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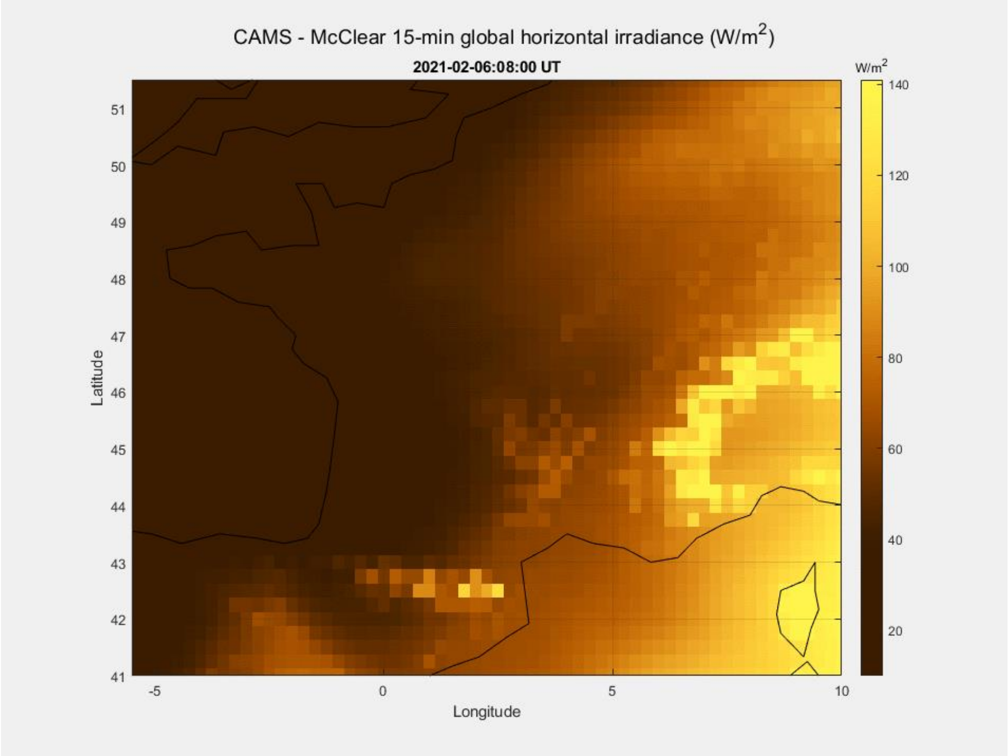
Earth Observation (EO) data for clear-sky irradiance

- From McClear (CAMS), which integrates aerosols, water vapor depending on the Sun topocentric position

Atmosphere Monitoring Service
atmosphere.copernicus.eu

The sky over Lyon turned a dramatic colour today thanks to sand from the Sahara Desert



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Earth Observation (EO) data for all-sky irradiance

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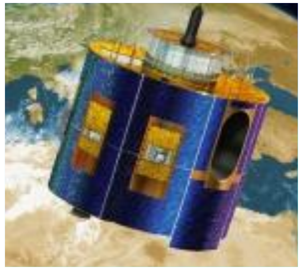
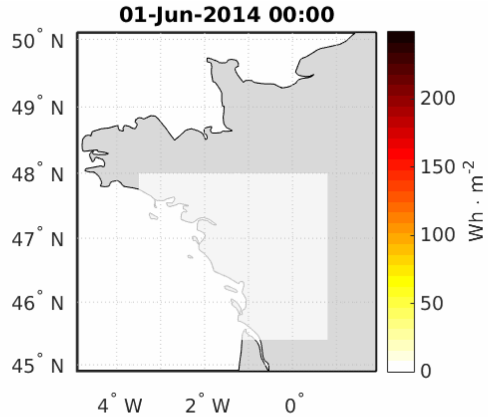
Atmosphere Monitoring Service
atmosphere.copernicus.eu

- Based on images from SEVIRI spaceborne by Meteosat Second Generation (MSG)





e-shape
EuroGEO GEO GROUP ON EARTH OBSERVATIONS Copernicus
The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Earth Observation (EO) data for all-sky irradiance

- Satellite-based all-sky solar data HelioClim-3 / CAMS Rad (3 km, 15 min, 2004-, 15+ years)
- Based on images from SEVIRI spaceborne by Meteosat Second Generation (MSG)
- At least one year of in-situ pyranometric measurements for local calibration

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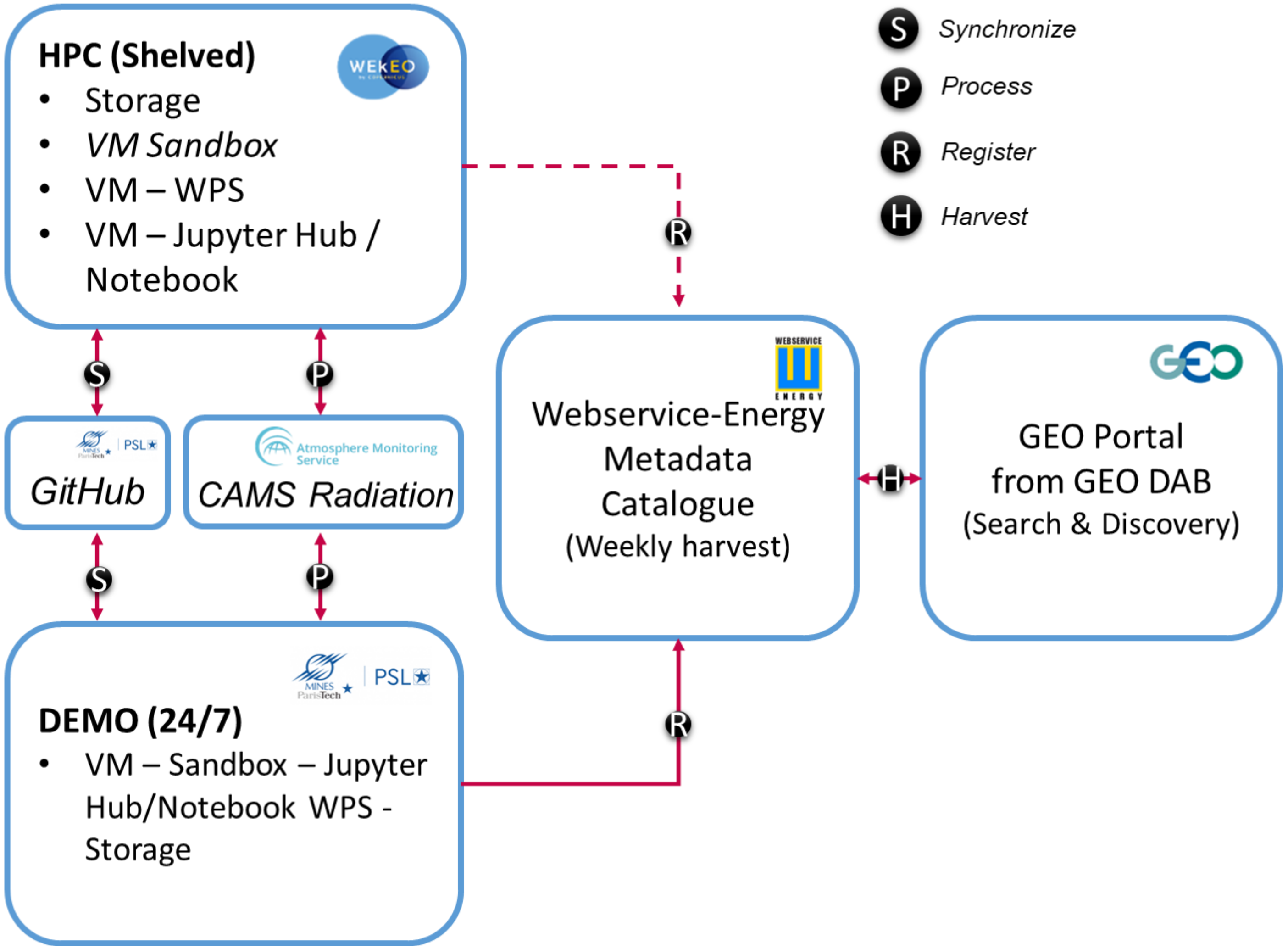
WebProcessing architecture and workflow



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