# inDust

## *Online Solar Workshop*

# Use of satellite data to assess and forecast solar energy potential in cities: from solar cadaster to PV variability at urban scale


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e-shape

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

# EuroGEO Showcases Applications Powered by Europe

- European contribution to GEO establishing EuroGEO
- 15M€, 60 partners, 7 showcases, 32 pilots
- 4 years grant (2019-2023)
- ARMINES (France) coordinator – [e-shape.eu](e-shape.eu)


- Promoting **users' uptake** of European Earth Observation (EO) 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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# Solar Cadaster: high resolution (metric) urban solar mapping

- Photovoltaic (PV) systems (rooftop, parking shades, etc.) in urban areas are very interesting
  - No emission of pollutants nor GHGs during their exploitation
  - Production of electricity where this electricity is consumed
  - Added value to unused urban roofs / parking shades (e.g. commercial centre)
- Solar Cadasters enable to:
  - Analyse the solar potential of roofs / shades over a city w.r.t. the local electricity consumption
  - Help public or private decision-makers and investors,



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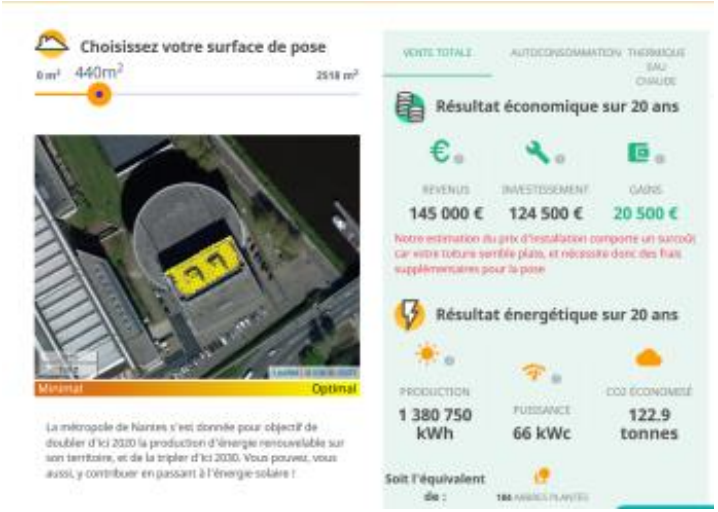
# Solar Cadaster from In Sun We Trust

- **In Sun We Trust** 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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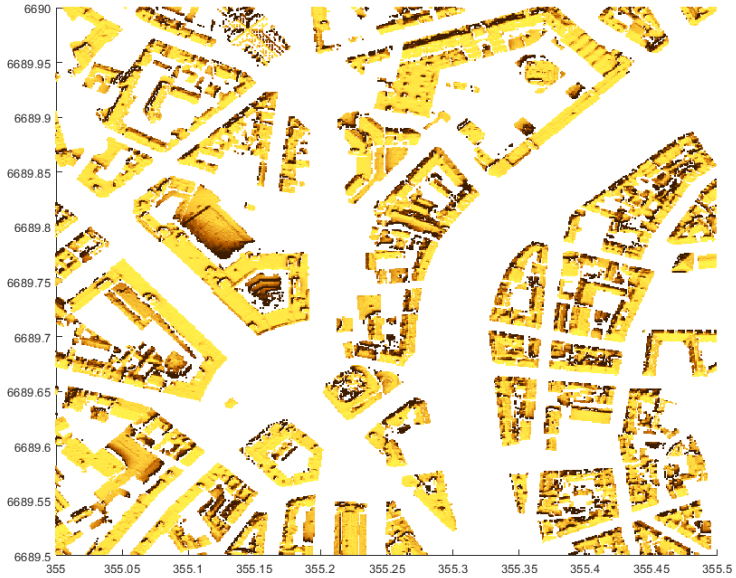
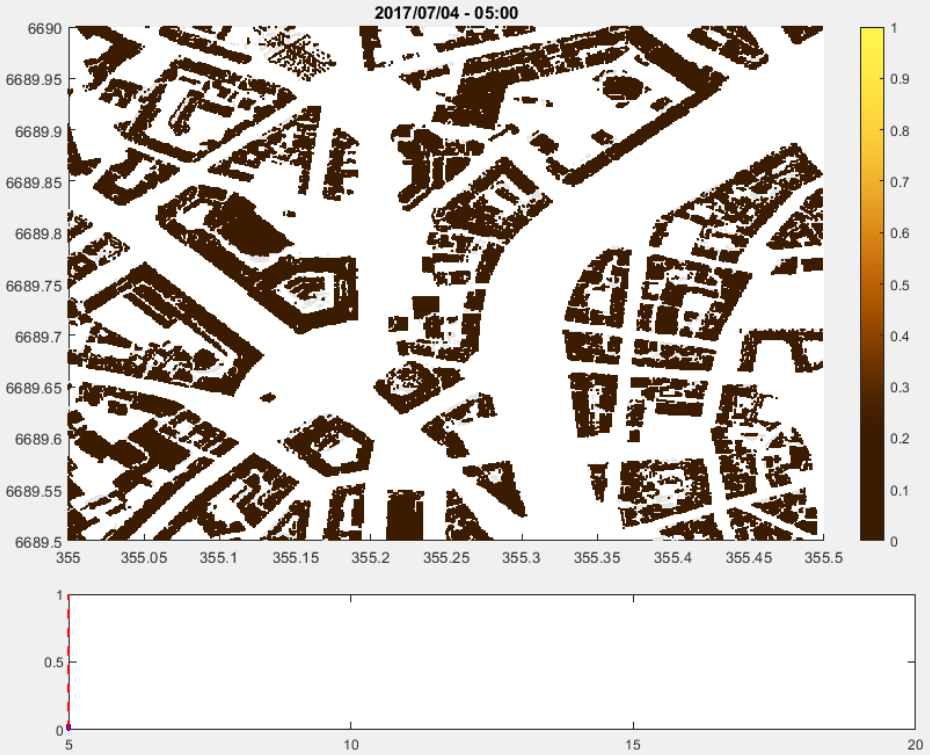
# From Solar Cadaster to urban-scale solar variability

**Static yearly irradiation on tilted plans (1-m res.)**




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

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# Pilot #2: High PV penetration in urban area

- **Objective:** develop GIS-tools dedicated to **high photovoltaic penetration** at urban scale, providing **EO based information** about **urban energy system** modeling, electric energy demand profiles and accurate electric production of fleet of **PV rooftop systems**
- **Expected user community:** Urban planners, grid operators, aggregator for energy trading, researchers in Energy and Urban planning and citizens (self-consumption)
- **Two parts of the pilot:**
  - **part 1: PV variability at urban scale (pilot in Nantes)**
  - Part 2: EO-data for PV integration in the urban energy system (pilot in Oldenburg)
- **Partners:**

ARMINES, MINES ParisTech, PSL, TRANSVALOR, DLR

- **Supporting infrastructure:** DIAS WEkEO, Urban TEP

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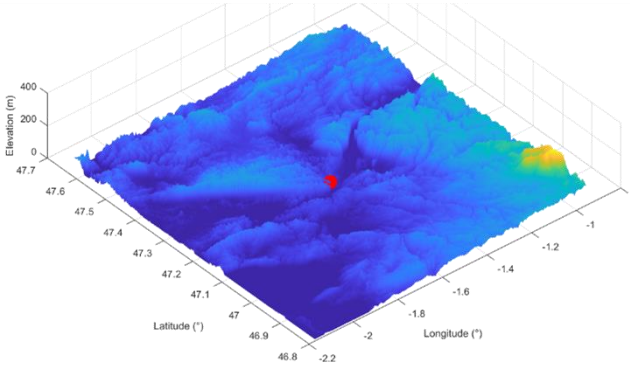
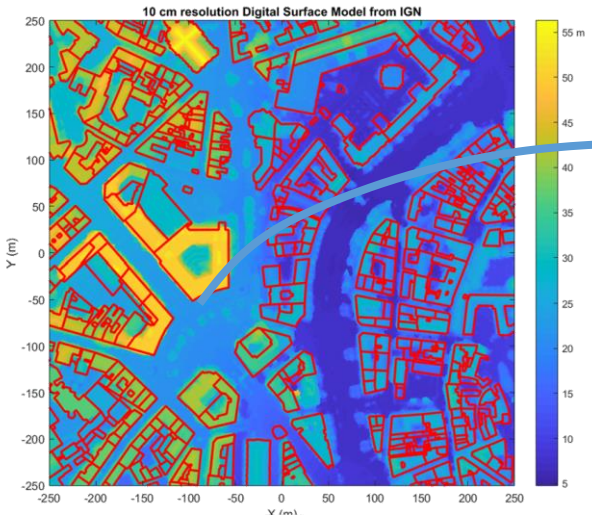
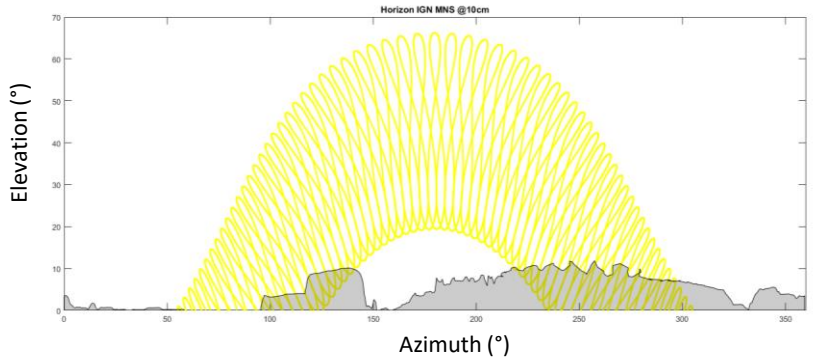
# The EO data

- 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©)




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

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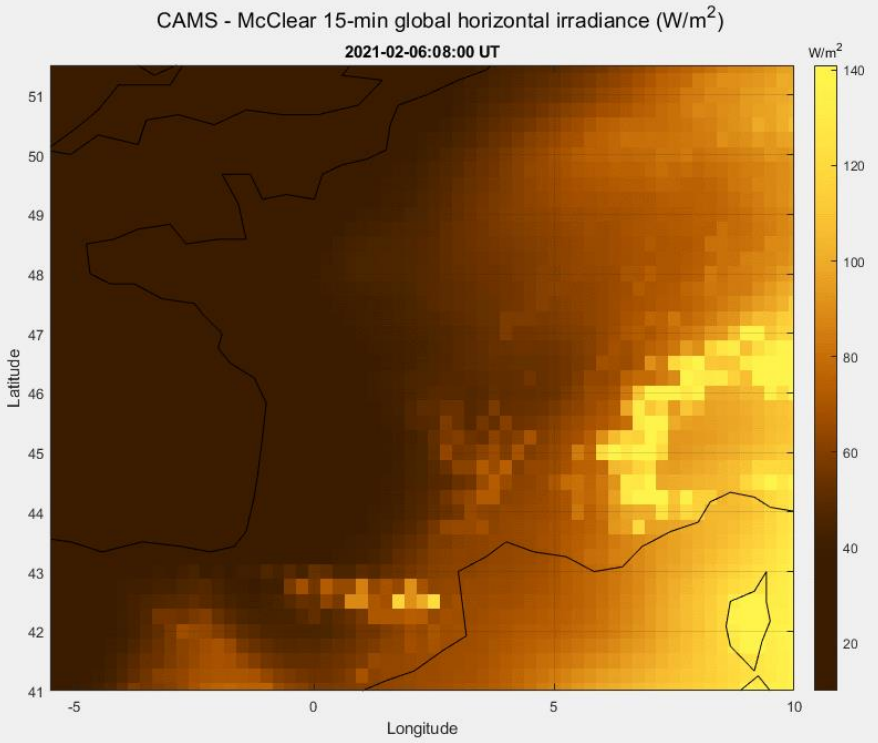
# The EO data for clear-sky irradiance modeling

- *Clouds are not the only source of solar variability*
  Irradiance for clear-sky (cloud-free) condition
  from McClear (CAMS), integrating 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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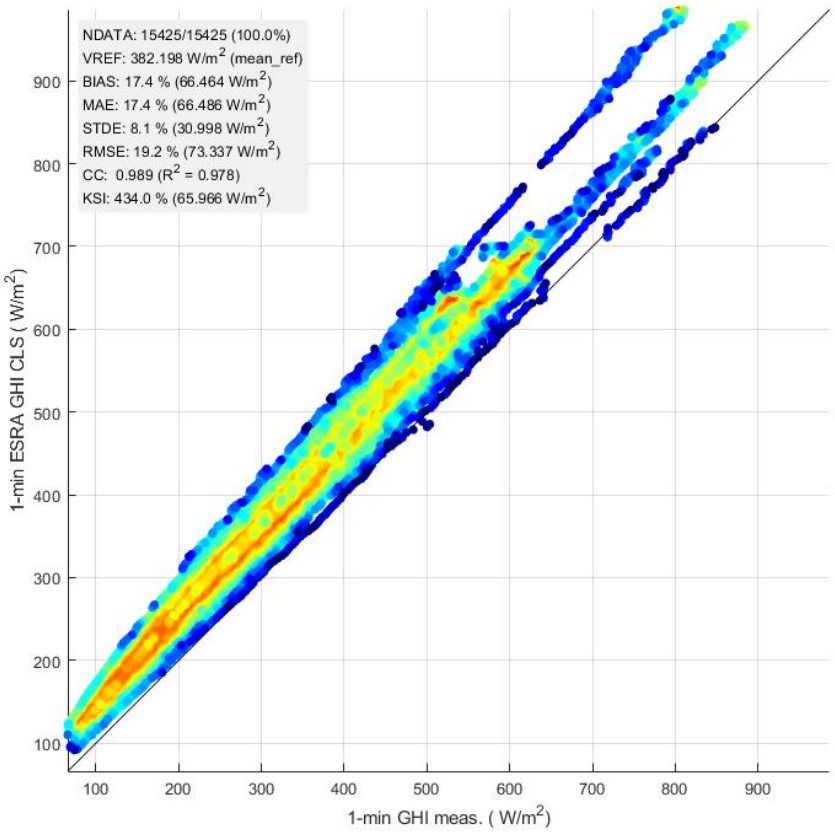
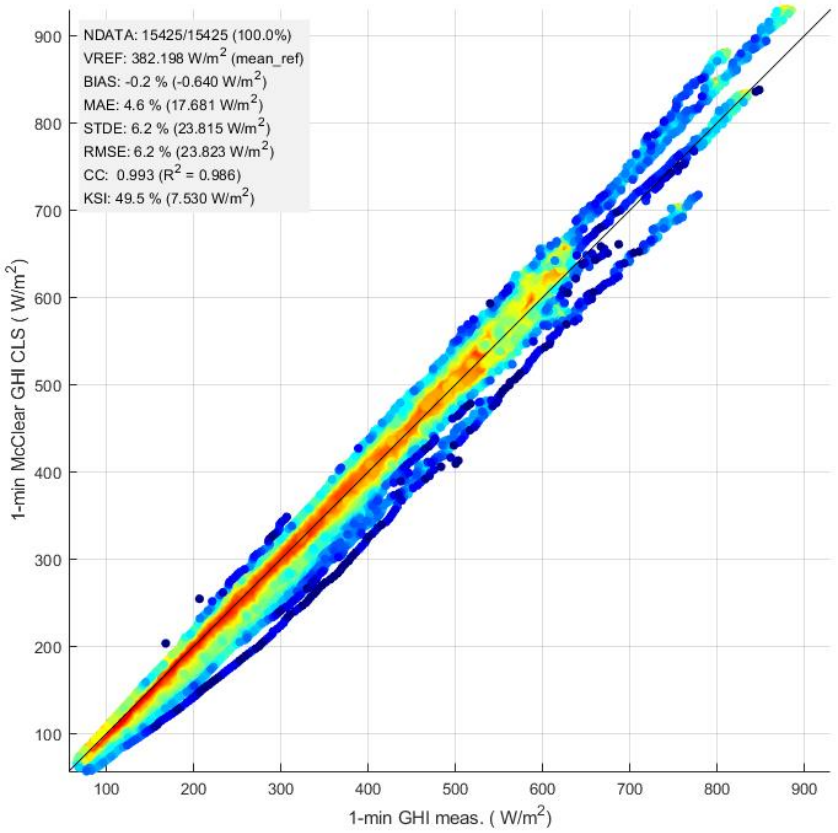
# The EO data for clear-sky irradiance modeling

- Example with in-situ measurements under clear-sky in Shanghai

Clear-Sky GHI with Climatology Monthly Linke Turbidity (ESRA Model)




Clear-Sky GHI from McClear (Aerosol + WV from CAMS)

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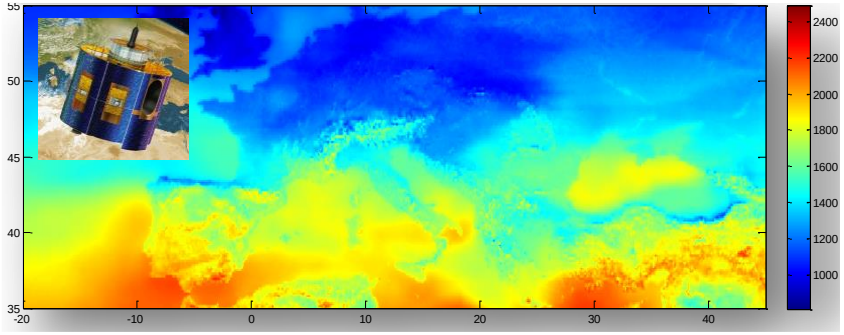
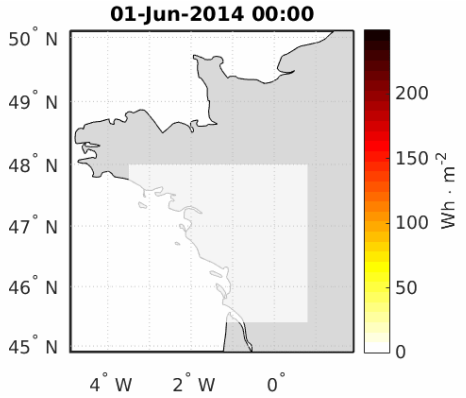
# The EO data for all-sky irradiance estimation

- Satellite-based all-sky solar data HelioClim-3 / CAMS Rad (3 km, 15 min, 2004-, 15+ years)
  - Heliosat-2 / Heliosat-4 methods
  - Applied on images from SEVIRI spaceborne by Meteosat Second Generation

Atmosphere Monitoring Service
atmosphere.copernicus.eu




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

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# Data and Information Access Services (DIAS)

- DIAS WEkEO

  - Providing **cloud processing** requested on-the-fly through asynchronous **OGC Web Processing Services (WPS)**

  - Hosting a **Jupyter Hub** with **Jupyter Notebooks** exemplifying in **Python different use-cases** with:
    - GIS-like interface
    - WPS asynchronous requests
    - Output data exploitation and representation

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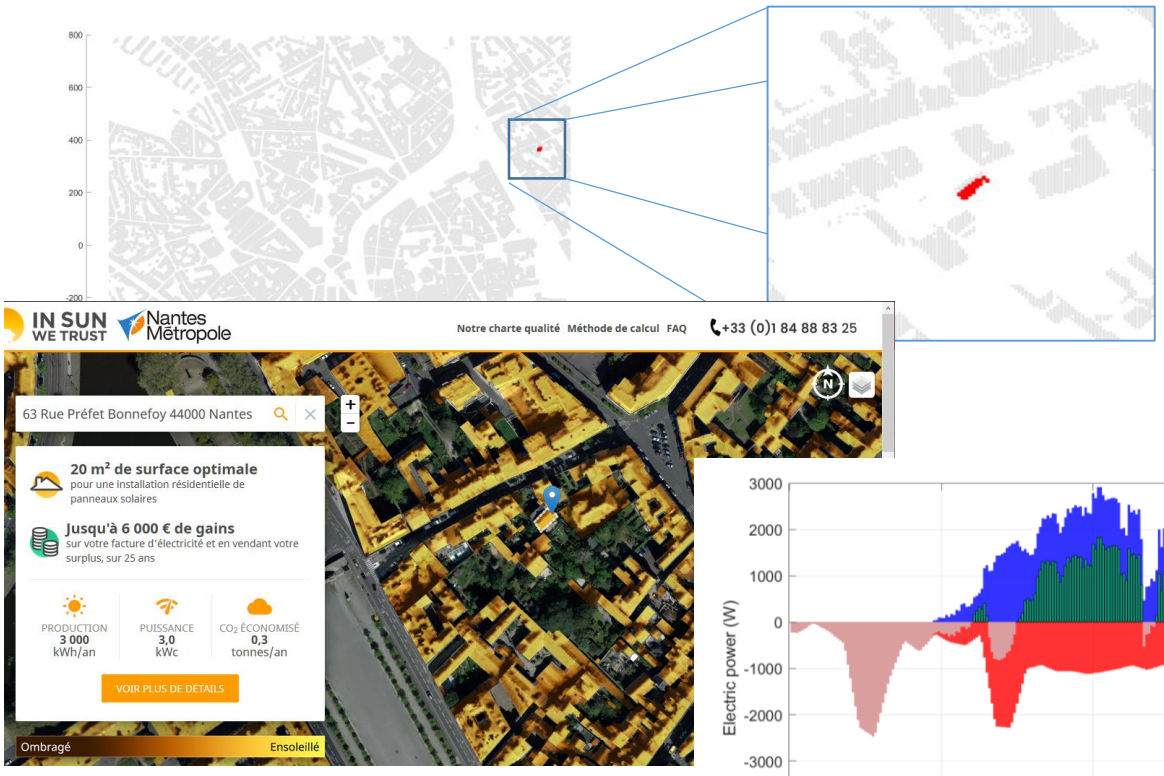
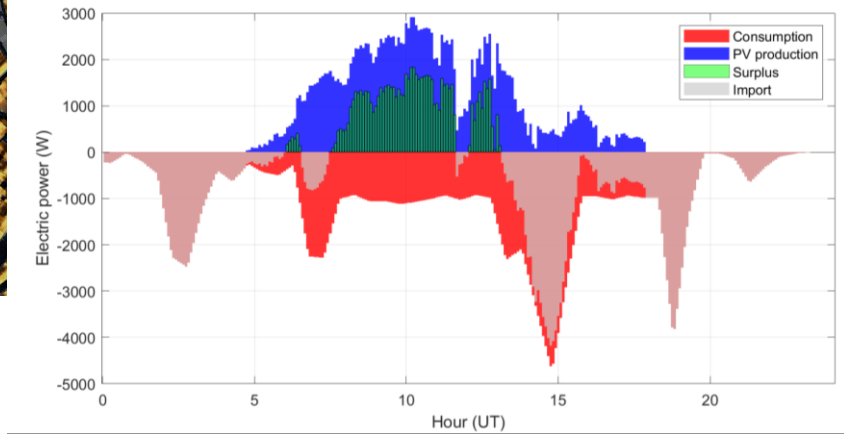
# Historical analysis of PV variability (case #1)

- Usage: PV self-consumption (sizing individual systems, 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

High_PV_in_urban_area-Self_c

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

jupyterhub High_PV_in_urban_area-Self_consumption (autosaved)

Se déconnecter | Control Panel

Fichier Édition Affichage Insérer Cellule Noyau Navigate Widgets Aide

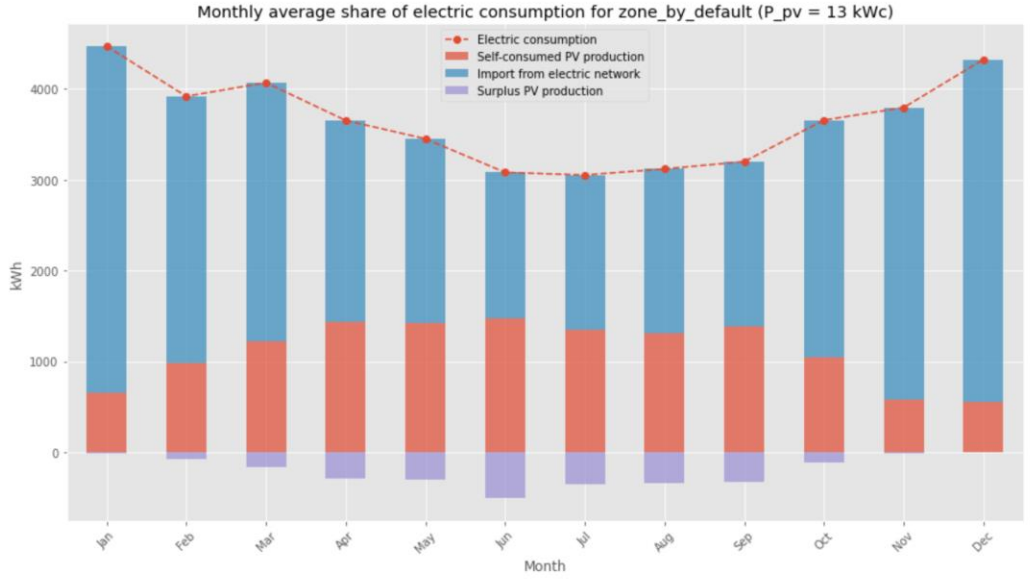
Trusted | Python [conda env:eshape]

Run | Markdown | nbdiff | Memory:

**Contents**




In [22]:
```
# Time series of monthly consumption, PV production, PV self consumed, PV surplus
SC.plot_monthly_ts()
```



# 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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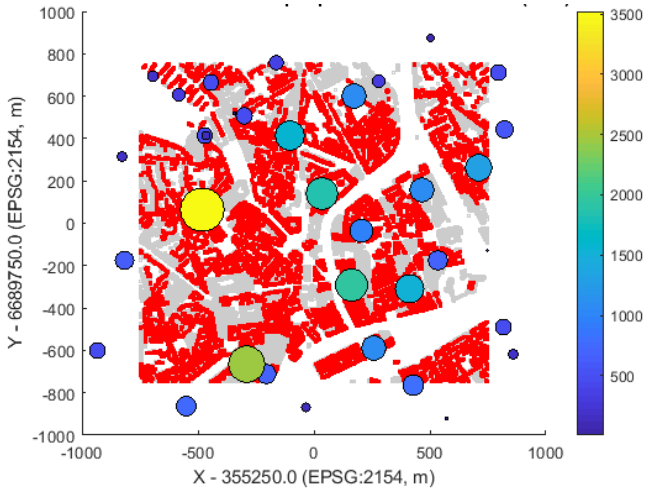
# Historical analysis of PV variability (case #2)

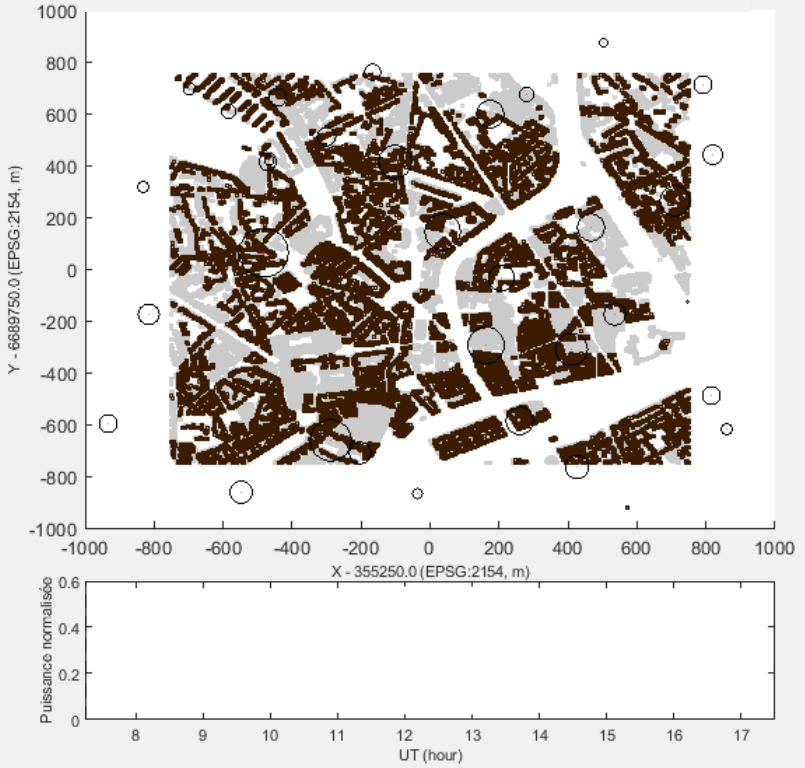
- Usage : Simulated PV injection in different source points of the electric grid for different scenarios of PV penetration (for DSO, e.g. ENEDIS)

Example: urban area of of 1.5 km x 1.5 km
**20 % PV penetration:**
35 related source points of ENEDIS (DSO)
14 ha of PV roof-top 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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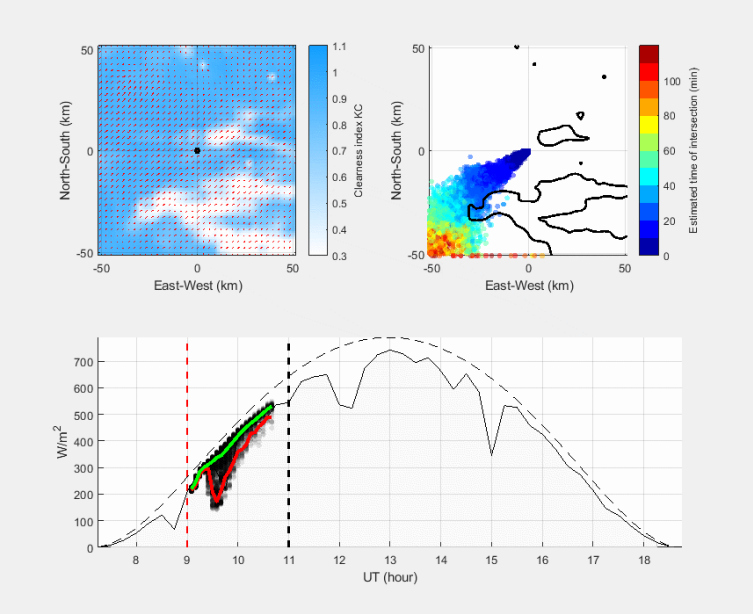
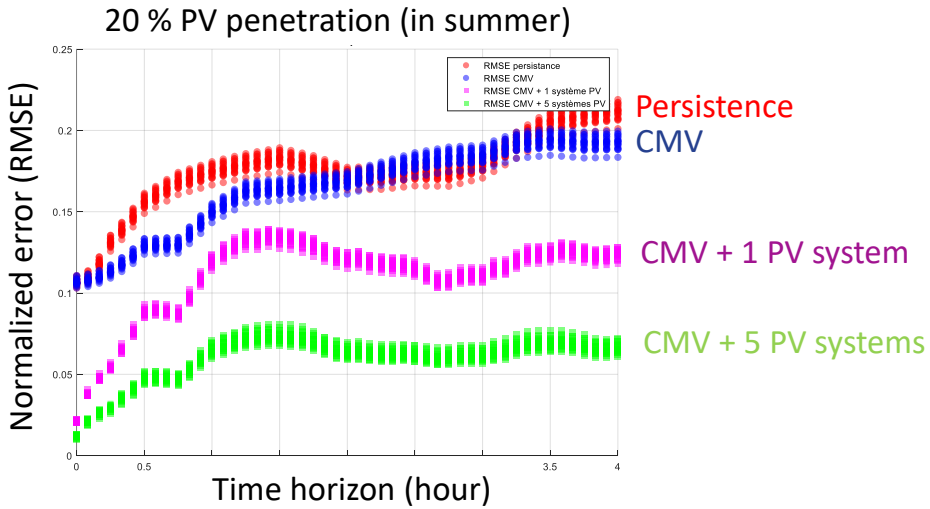
# PV nowcasting and short-term forecasting (case #3)

- Usage: Energy trading with portfolio of PV rooftop systems (e.g. 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
- Potential use of some PV yield monitoring (*in-situ*) in the real time loop of forecasting correction

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