Probabilistic short-term solar forecasting in urban areas: an operational proposal under e-shape H2020

Rodrigo Amaro e Silva
MINES ParisTech / ARMINES
(rodrigo.amaro_e_silva@mines-paristech.fr)

PEARL PV Conference
14 March 2022

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

Programme

- Context
- Satellite-based probabilistic solar forecasting
- Solar forecasting at urban scale in e-shape H2020

The result from a team effort (alphabetical order):

Benoît Gschwind, Lionel Menard, Philippe Blanc, Thomas Carrière (Solaïs), Raphaël Jolivet, Romain Besseau, Yves-Marie Saint-Drenan, Fuqiang Zhang

MINES ParisTech | PSL

Centre Observation, Impacts, Énergie
Renewables, Life Cycle Assessment, Earth Observation

O.I.E.

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

Assumptions for today

- Solar is good, fossils not so much

e-shape

EuroGEO GEO GROUP ON EARTH OBSERVATIONS Copernicus

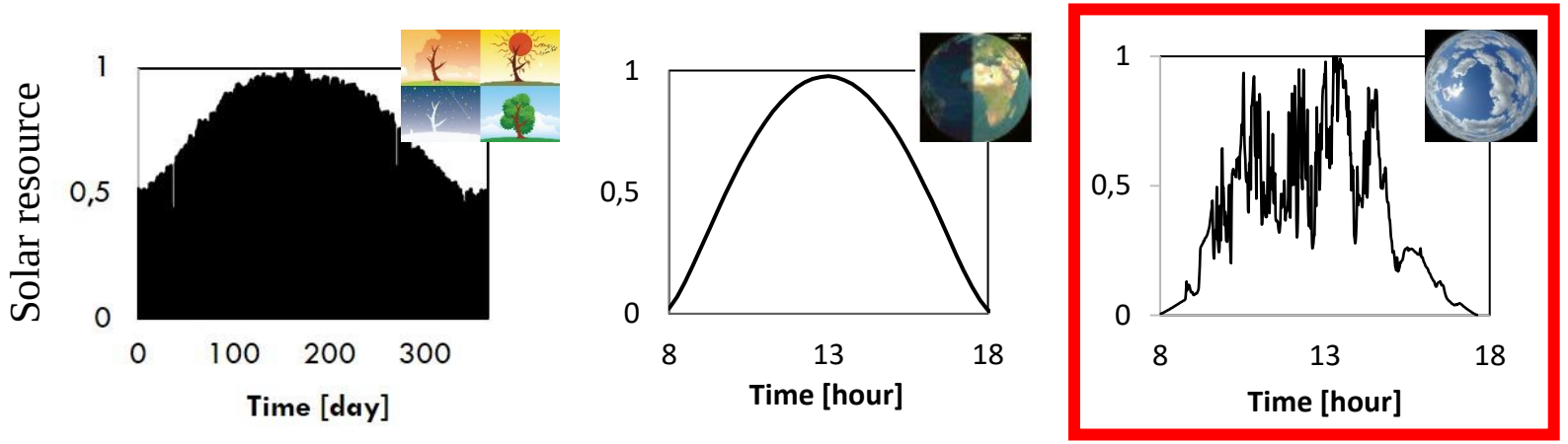
The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Starting with some context

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

Solar variability and uncertainty

Solar variability at different time scales



Ela et al. (2013) point out that

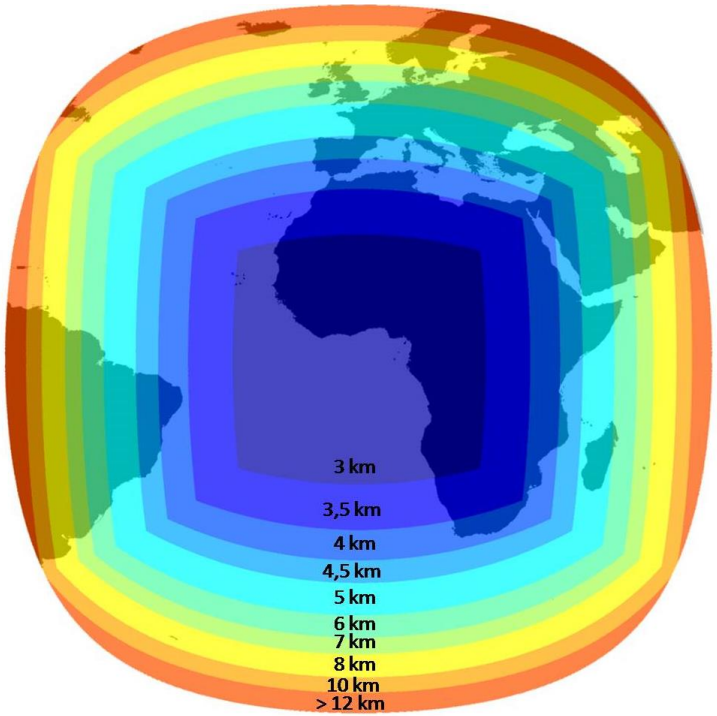
- High PV penetration can lead to load-generation mismatch (imbalance)
- 1/3 due to variability, **2/3 caused by uncertainty in solar forecasts**

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

Advantages of satellite-based solar data



- Good spatial coverage
- Interesting resolution (15+ min, 3+ km)
- Considerable historical records (10+ years)
- Several existing products (e.g. HelioClim-3)
- The physics background is clear

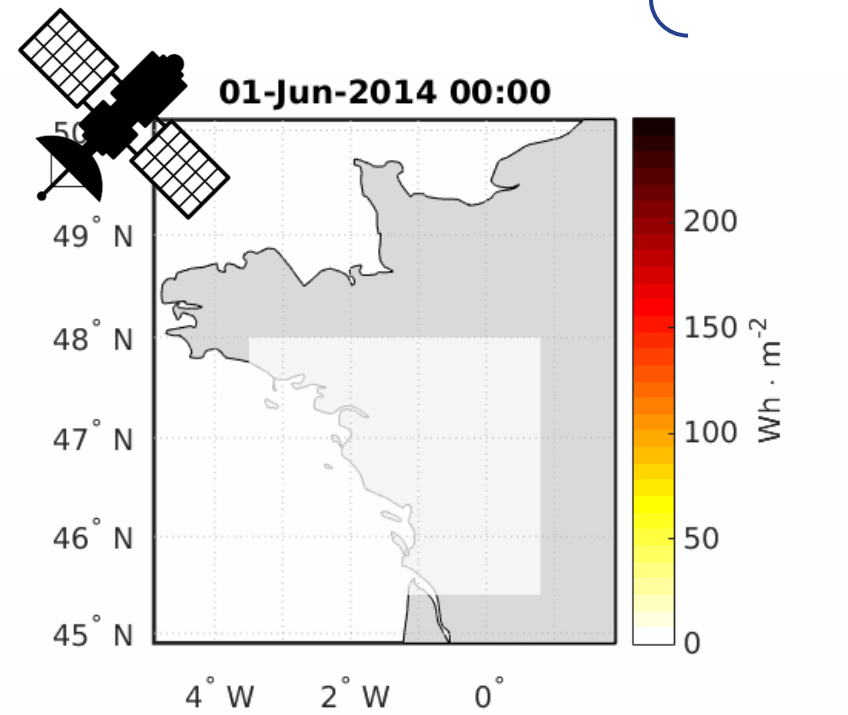
Figure from Solar Radiation Data (SoDa), www.soda-pro.com

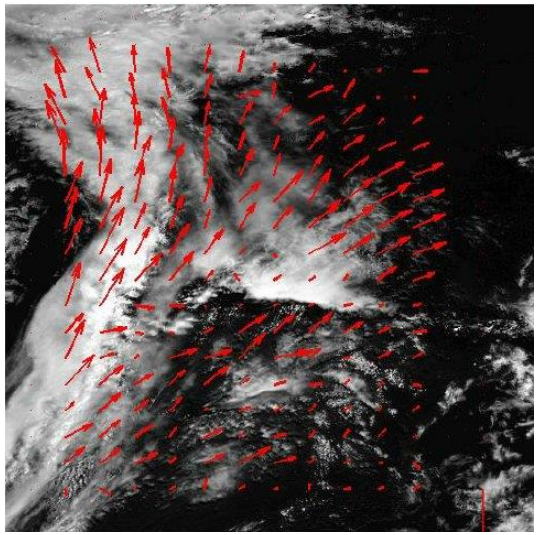
The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Satellite-driven solar forecasting

From satellite images, infer:

- Clear-sky index* (Kc)
- Cloud motion vectors (CMV)





*Proxy of cloud transmissivity

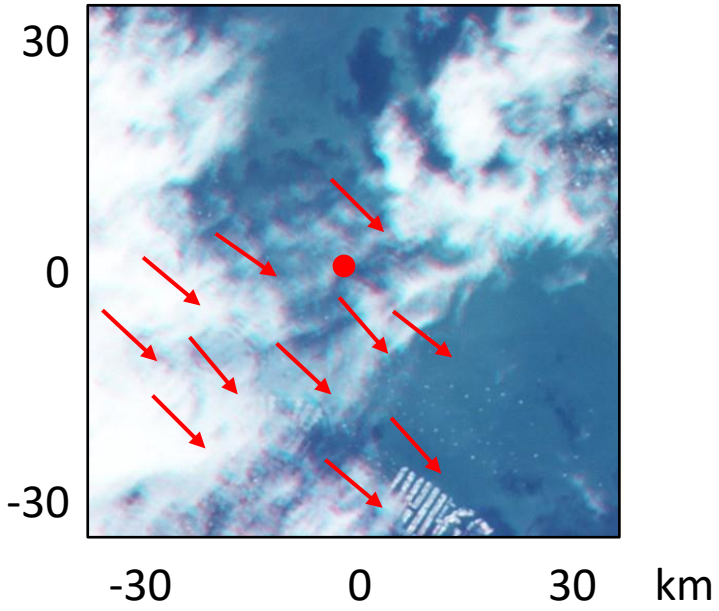
Left figure: courtesy from Prof. Philippe Blanc. Right figure: Sylvain Cros et al. (2014), 4th SIW @ Berlin

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

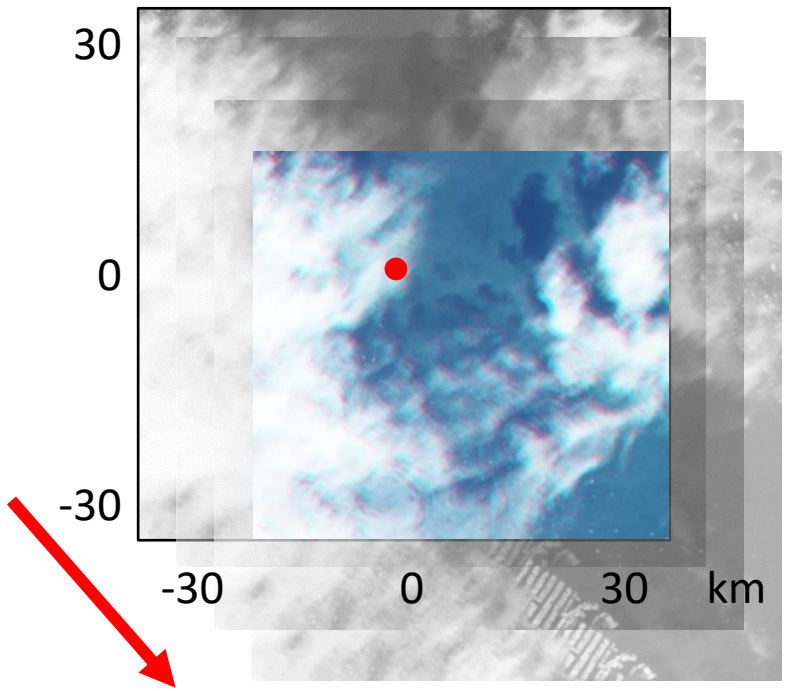
A simplistic illustration



1. Find dominant advection pattern (↘)

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

A simplistic illustration



1. Find dominant advection pattern (↘)
2. Move kc matrix accordingly
3. Kc forecast = advected Kc closest to point of interest (•)

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

But all approaches seem to produce

deterministic forecasts

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

Deterministic vs probabilistic forecasts

How much PV in 1 hour?
(deterministic version)

0.8 kWh/kWp

Probabilistic version: **0.8 kWh/kWp**, **80% probability**

- Include an uncertainty layer to better manage risk

For a nice review on this, check Li et al. (2020) 10.1016/j.solener.2020.07.066

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

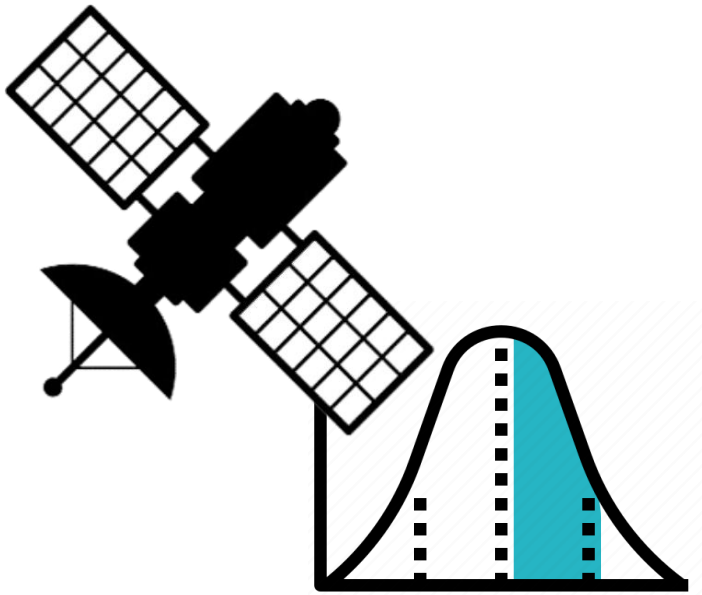
What we are doing on probabilistic solar forecasting

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

Our proposal!

A satellite-based probabilistic approach

- hybrid (physics + statistics)
- compatible with operational applications
- does not require in-situ measurements
  - but can benefit from it (if available)



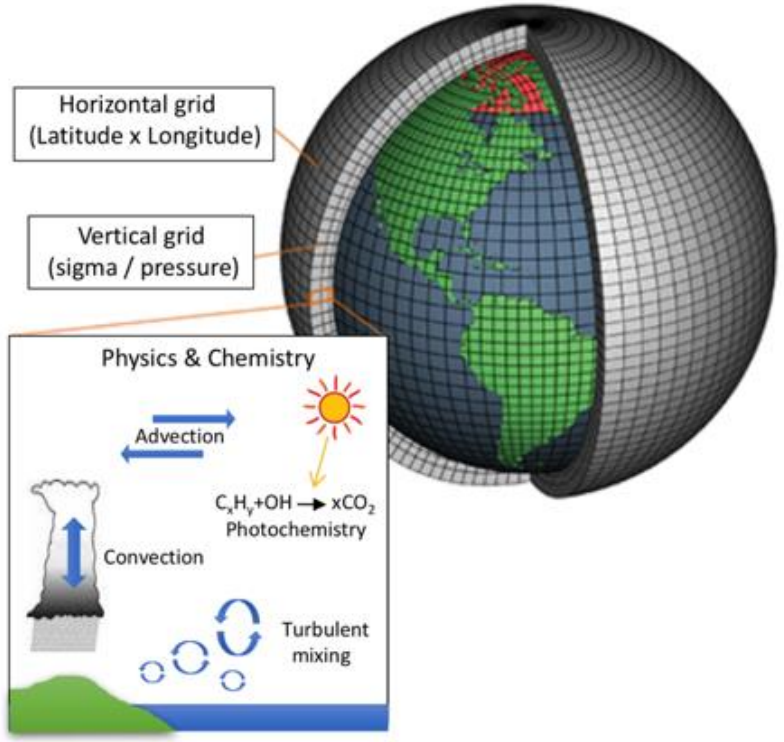
e-shape

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

Getting inspiration from NWP

Forecasting through modeling of the atmosphere dynamics



$$\rho\frac{\partial\vec{V}}{\partial t}+\rho\left(\vec{V}\cdot\nabla\right)\vec{V}=-\nabla p+\mu\nabla^2\vec{V}+\rho\vec{g}$$

Figure: wikipedia page on “Numerical weather prediction”

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

Getting inspiration from NWP

Input perturbation as a proxy of uncertainty (input → forecast)

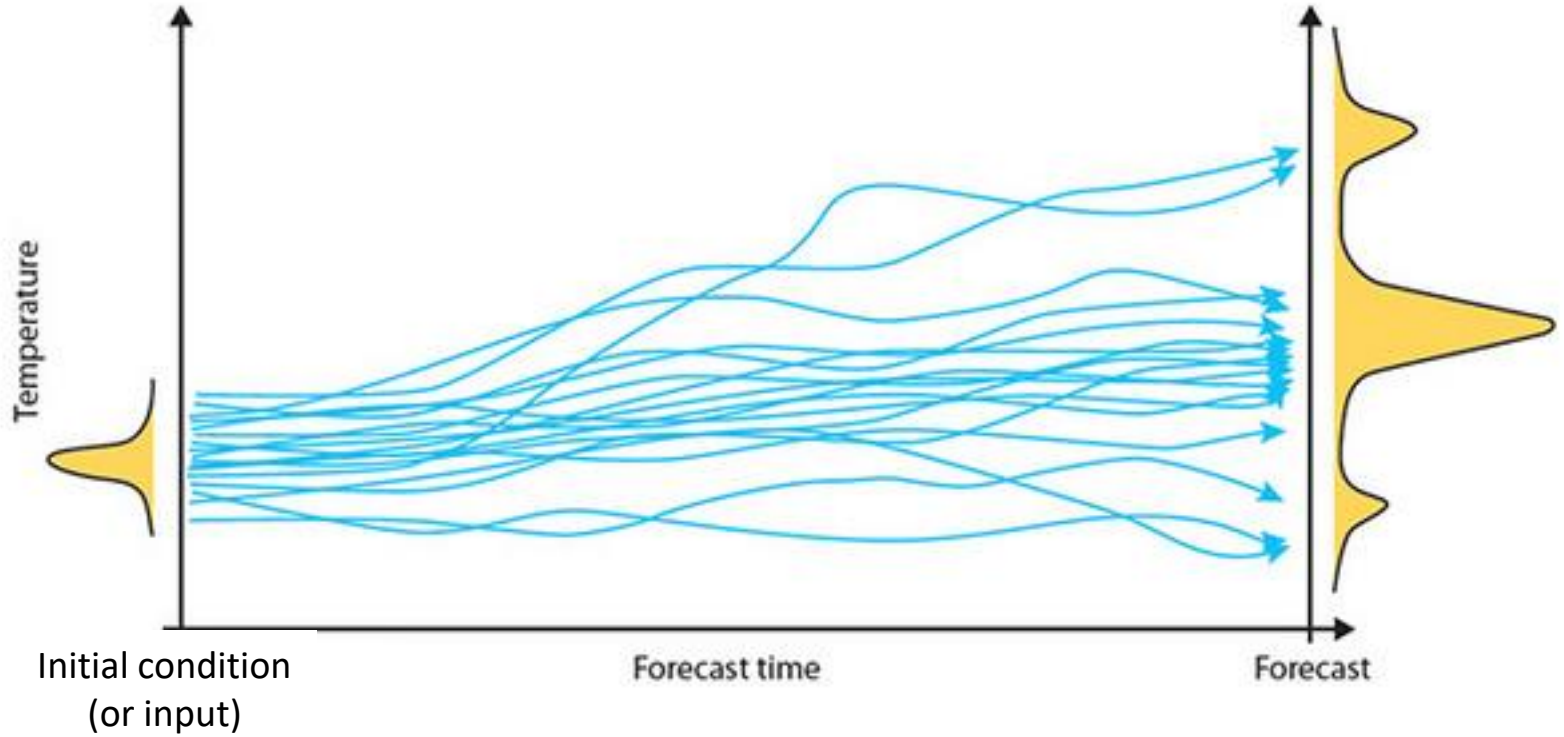


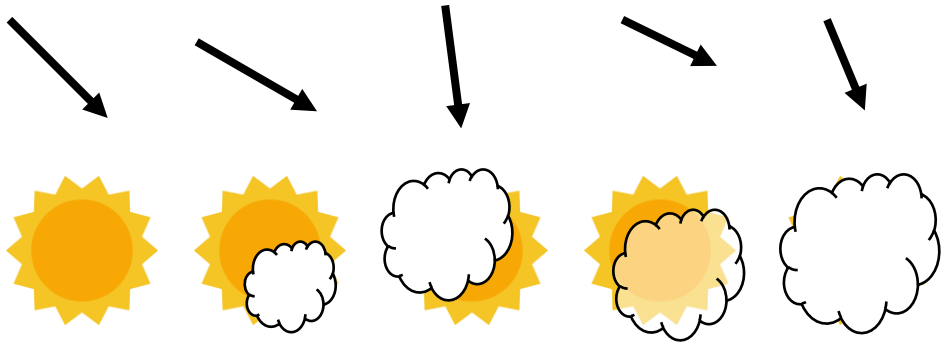
Figure: ECMWF Forecast User Guide, Section 5

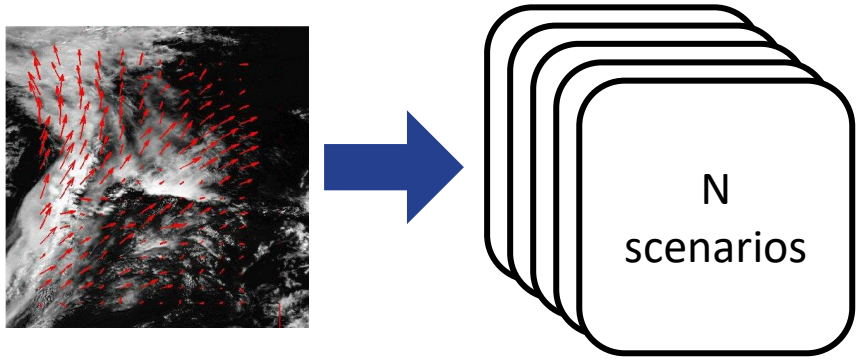
The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Why not perturbate satellite methods?

Generate scenarios adding a batch of Gaussian noise to

- CMV
- Kc



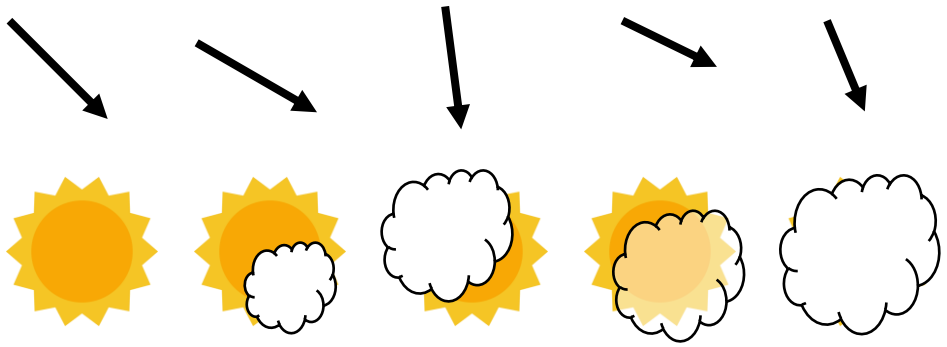


The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Why not perturbate satellite methods?

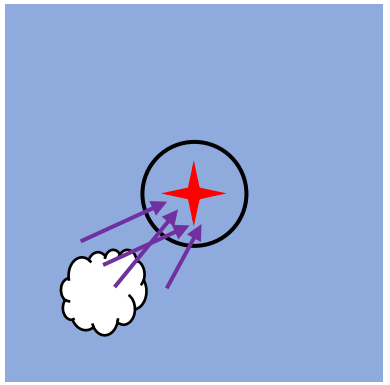
Generate scenarios adding a batch of Gaussian noise to

- CMV
- Kc



All scenarios consider a tolerance radius

- Possible set of points reaching the inside of the radius

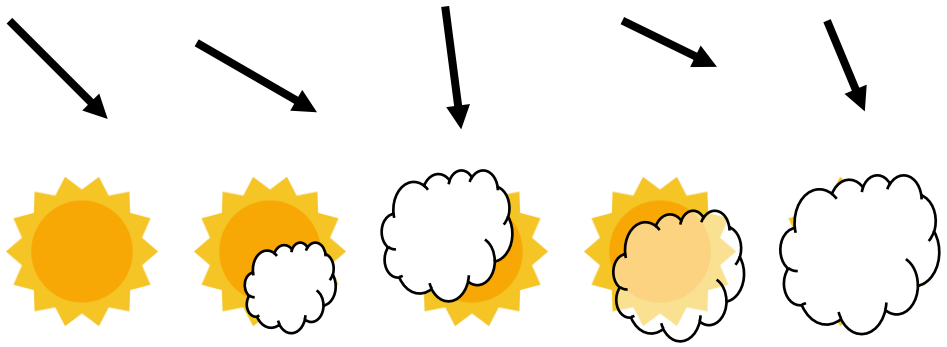


The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Why not perturbate satellite methods?

Generate scenarios adding a batch of Gaussian noise to

- CMV
- Kc

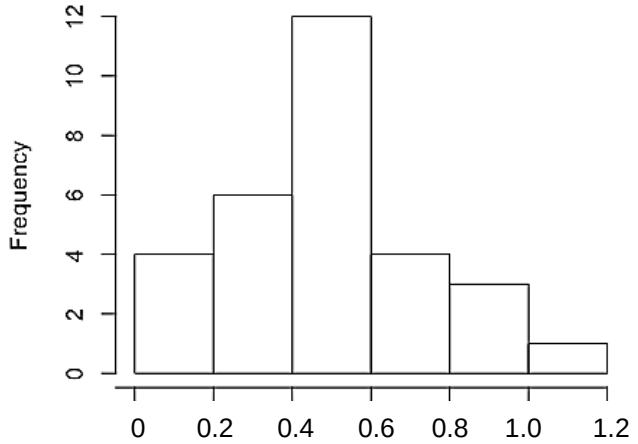


All scenarios consider a tolerance radius

- Possible set of points reaching the inside of the radius

Forecasting distribution

- Kc values from all reaching pixels from all scenarios

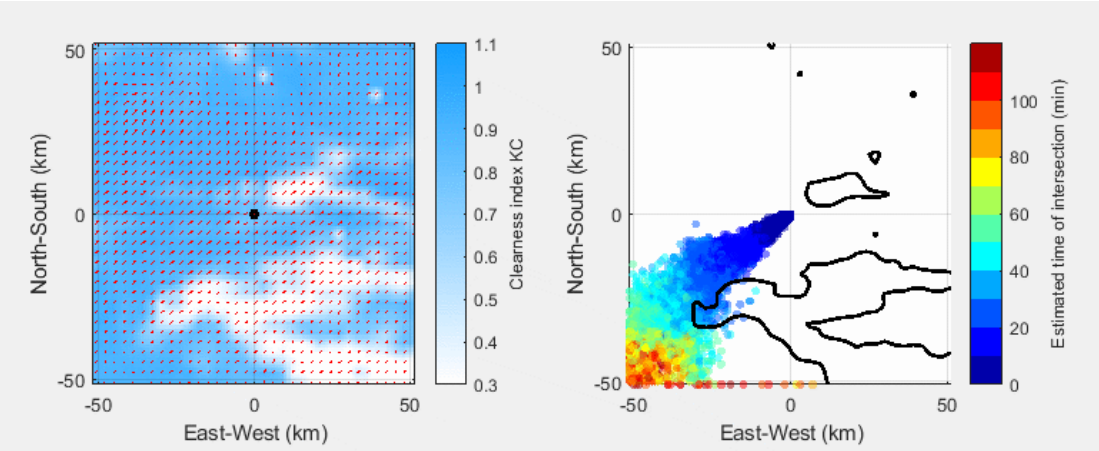


e-shape

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

An operational overview



Probabilistics
- Statistical trigger
- Physical modeling

Physical meaning to noise:

- uncertainty tied to the estimation of CMV and Kc estimation

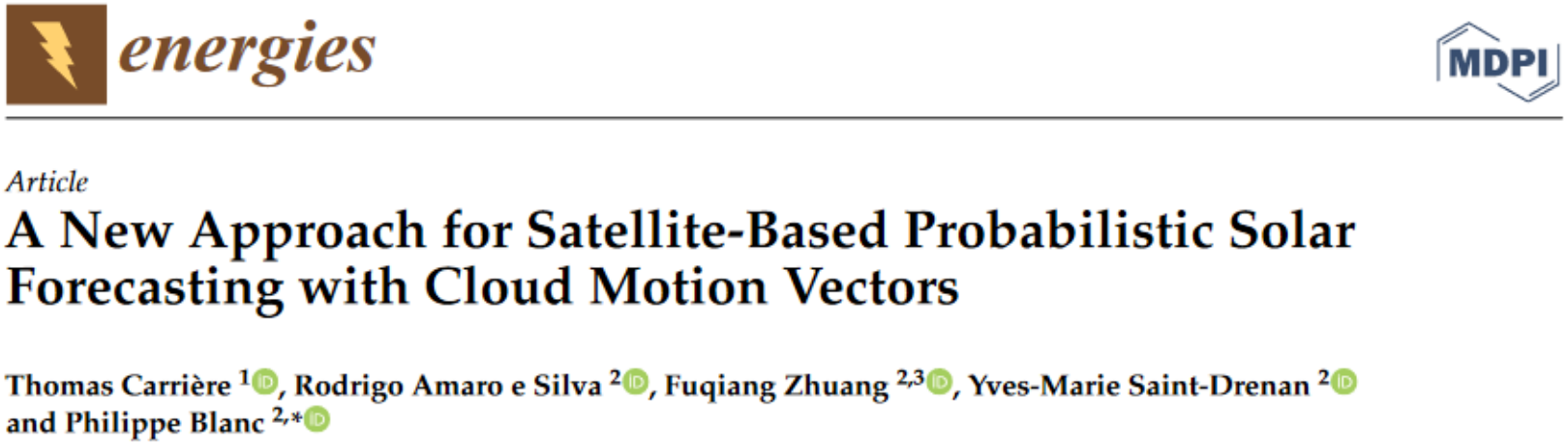
Animation: courtesy from Prof. Philippe Blanc

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

Super brief overview on case study & results

- 2 locations in France (Carpentras, Signes)
- 2 years of satellite and in-situ GHI records
- Performs well vs benchmark (CRPS*, PINAW*)

SOLAÏS


energies

MDPI

Article

A New Approach for Satellite-Based Probabilistic Solar Forecasting with Cloud Motion Vectors

Thomas Carrière [1], Rodrigo Amaro e Silva [2], Fuqiang Zhuang [2,3], Yves-Marie Saint-Drenan [2] and Philippe Blanc [2,*]

SCAN ME

* If you're curious about probabilistic metrics, check Lauret et al. (2019), 10.1016/j.solener.2019.10.041

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

How we are using this for solar forecasting in urban areas (and why)

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

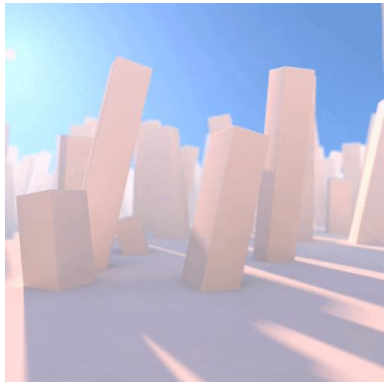
Our forecasting work in e-shape H2020 project

e-shape
EuroGEO Showcases: Applications Powered by Europe

Pilot 3.2 - High PV penetration in urban areas

(developing GIS-like PV integration tools at urban scale)

Coupling solar forecasting model & dynamic solar cadaster



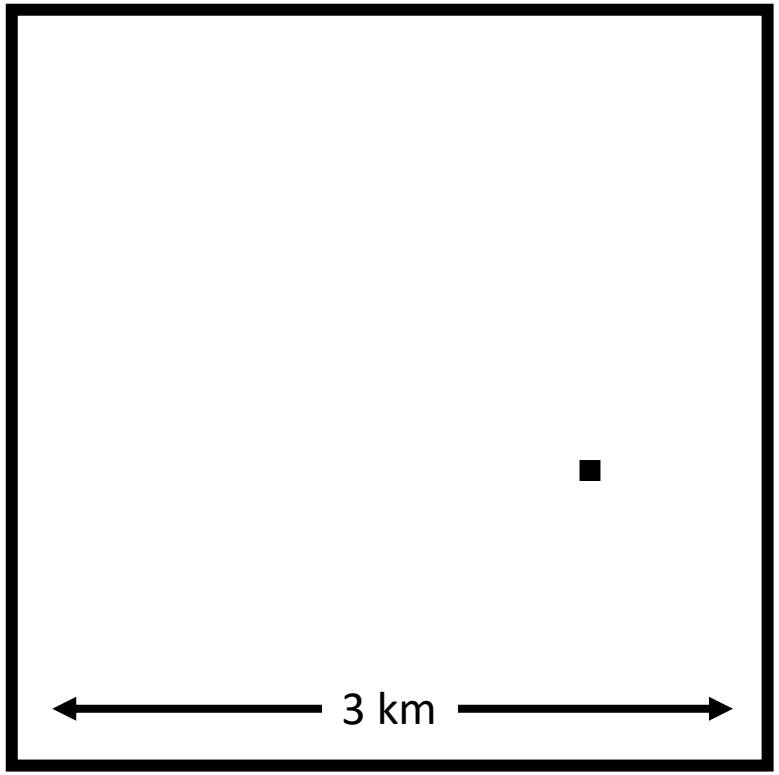
If you want to know more about the e-shape project and our work, check 10.13140/RG.2.2.13278.51522

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

Relevance of dynamic solar cadaster

It’s all a matter of spatial scale

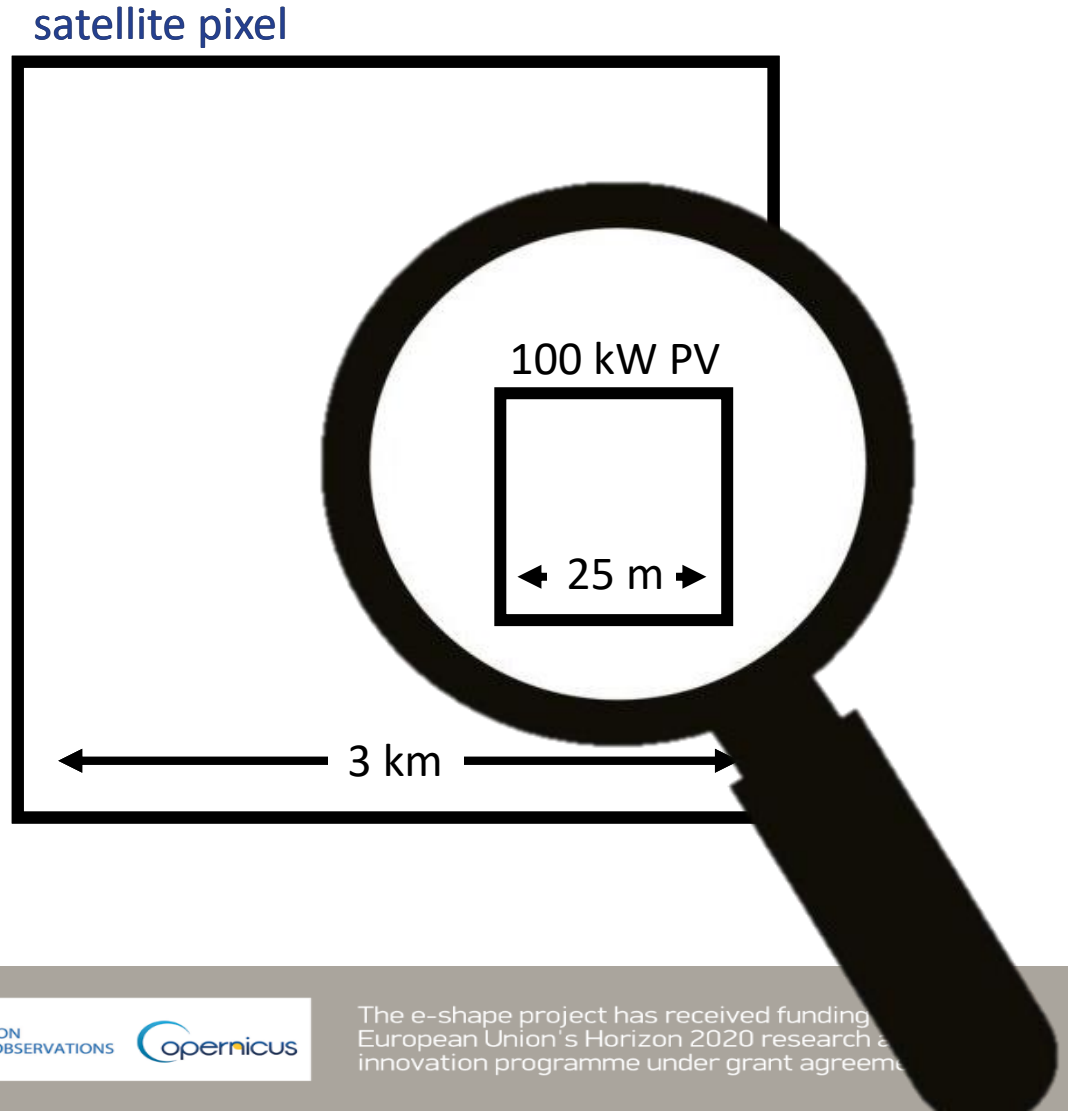
satellite pixel



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

Relevance of dynamic solar cadaster

It’s all a matter of spatial scale



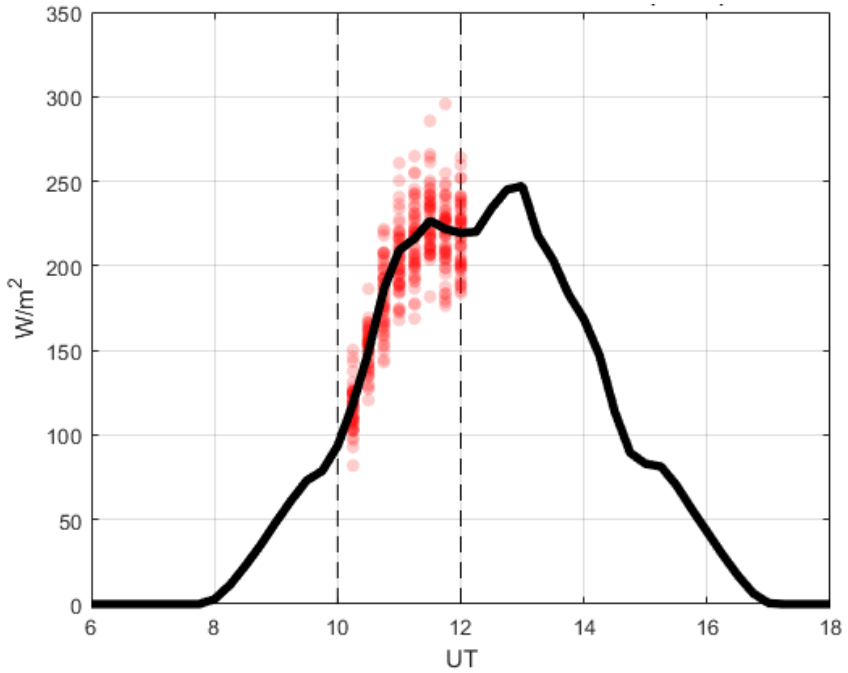
e-shape

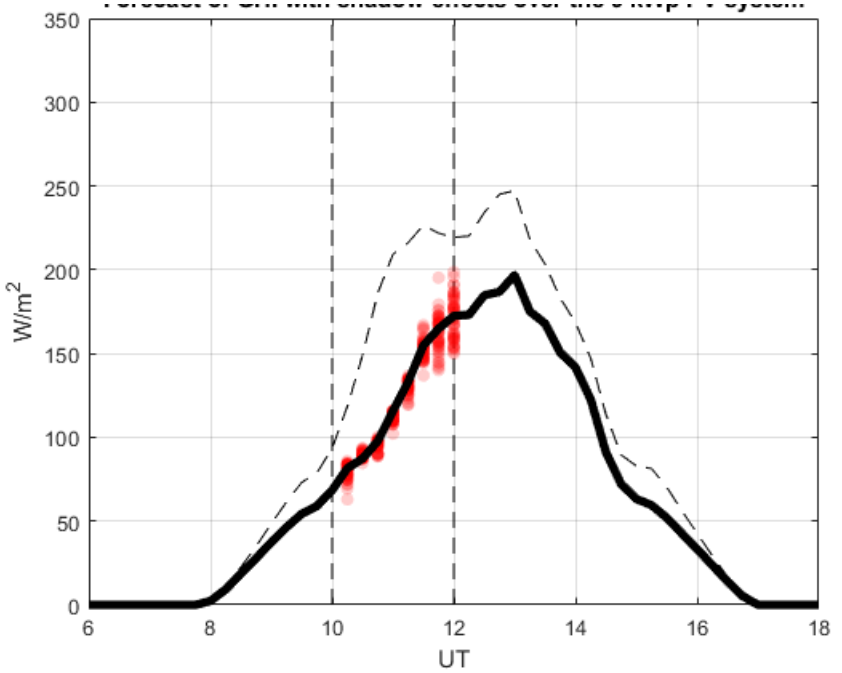
EuroGEO GEO GROUP ON EARTH OBSERVATIONS Copernicus

The e-shape project has received funding
European Union's Horizon 2020 research a
innovation programme under grant agreem

Relevance of dynamic solar cadaster

With a great impact on our forecast



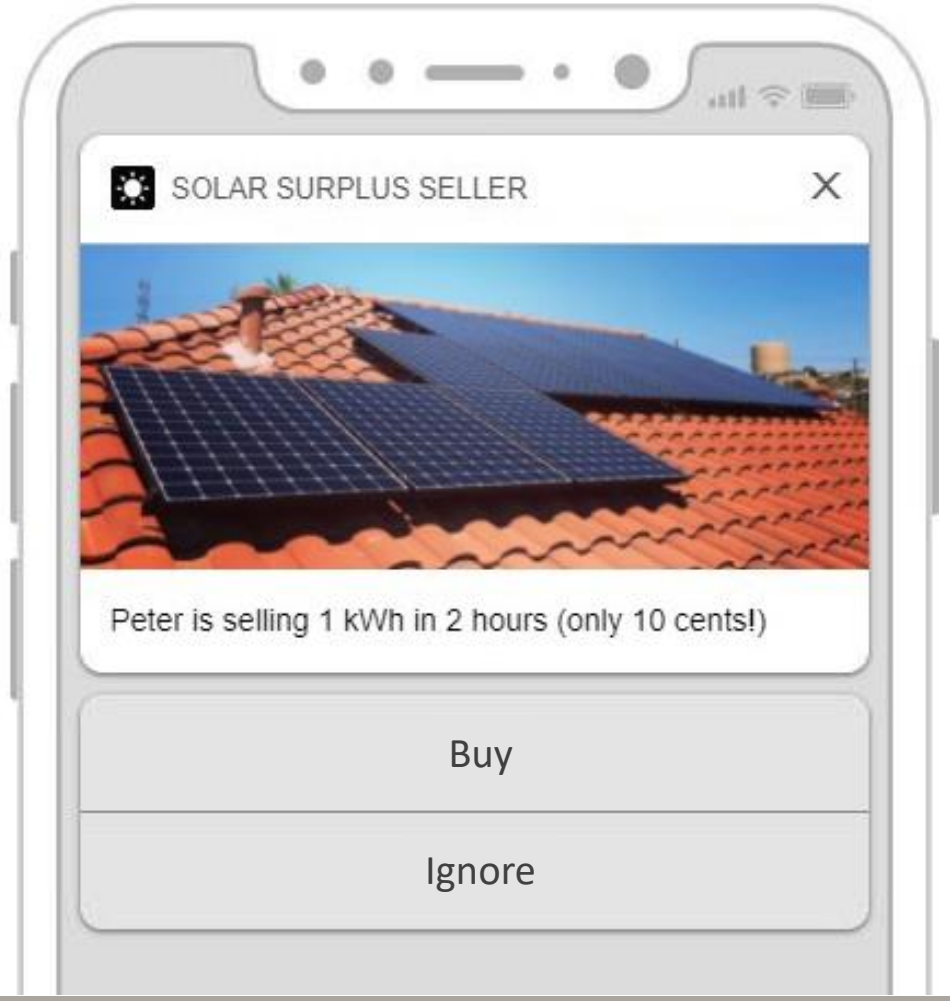


We could overestimate it by 10-100% !

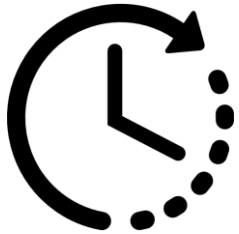
Figures: courtesy from Prof. Philippe Blanc

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

Our use-case for this topic: PV energy trading



Quantity
(1 kWh)



Horizon
(in 2 hours)

Forecasting = business enabler

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

Rodrigo AMARO E SILVA
MINES ParisTech, PSL Research University
Center Observation, Impacts, Energy

Postdoc Researcher
e-shape H2020 project

rodrigo.amaro_e_silva@mines-paristech.fr

www.mines-paristech.fr
www.oie.mines-paristech.fr

ed funding from the
) research and
rant agreement 820852

A brief overview on e-shape H2020 project

e-shape

EuroGEO Showcases: Applications Powered by Europe

https://e-shape.eu/

4 years grant (2019-2023)

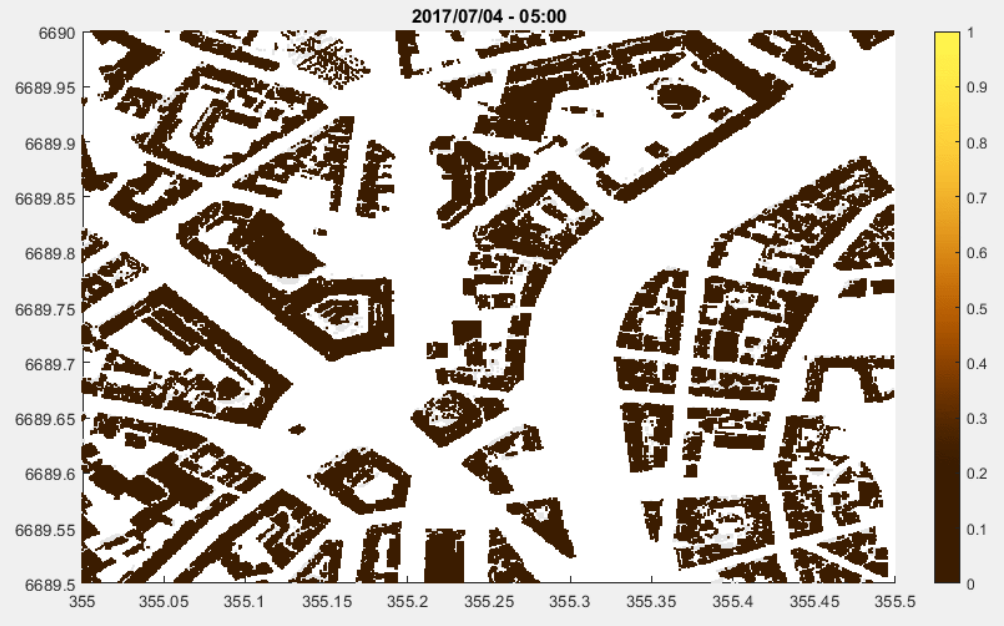
renewable energy

60 partners, 7 showcases

Pilot 3.2 - High PV penetration in urban areas

(developing GIS-like PV integration tools at urban scale)

Use cases leveraged by dynamic solar cadaster + Earth Observation data



Animation: courtesy from Prof. Philippe Blanc

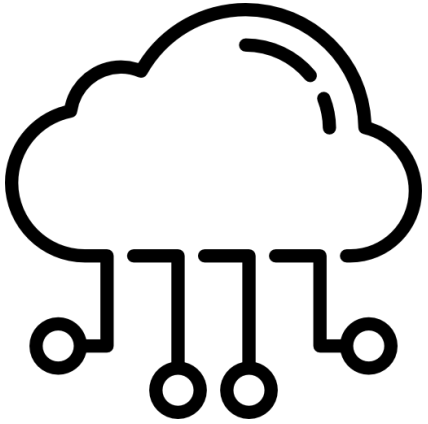
e-shape

EuroGEO GEO GROUP ON EARTH OBSERVATIONS Copernicus

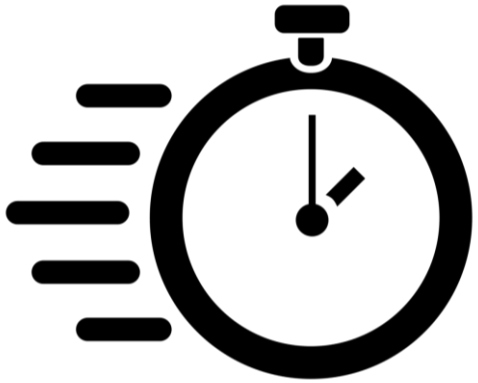
The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Key aspects of dynamic solar cadaster

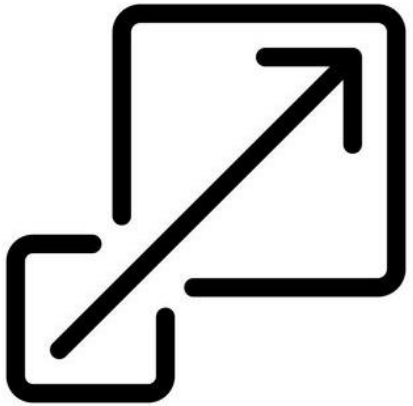
Solar calculations in urban environments based on Earth Observation data



Cloud-based



ON- demand the-fly



Scalable

Input agnostic

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

Leveraged use cases

#1 PV sizing for self-consumption

#2 PV injection at distribution grid level

#3 Forecasting for PV trading

#4 Shadowing impacts of new buildings

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