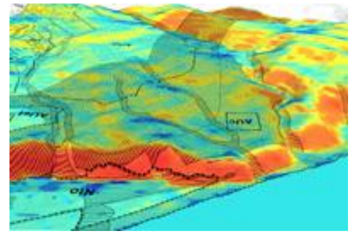
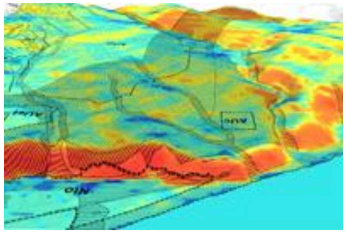


e-SPACE monitoring

FOSS4G 2017, Boston

Speaker: **Caroline Lallemand**

Reuniwatt



Solar **P**erformance **A**nalysis
and data **C**ollection
for **E**nergy **monitoring**

e-SPACE monitoring

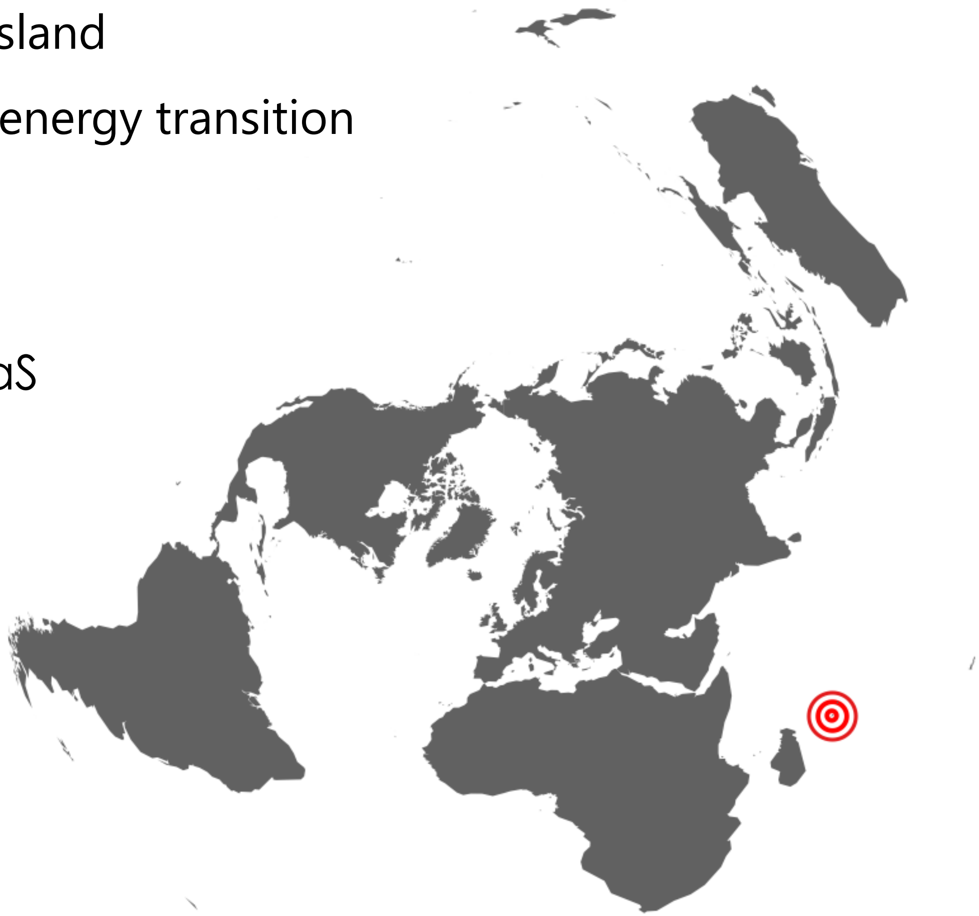
SME champion of a European space research and development project

Reuniwatt

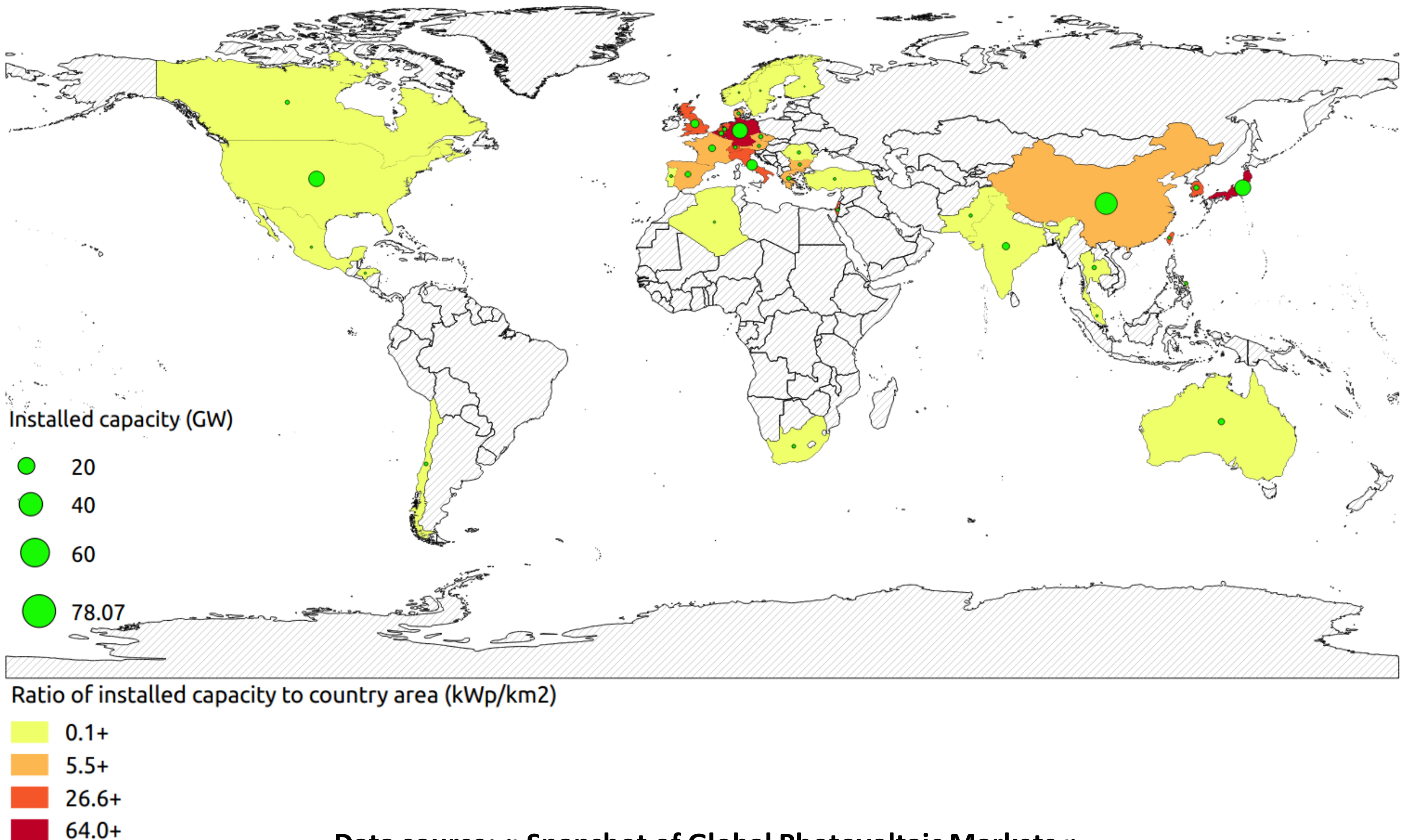
- A young company from Reunion Island
- Develops innovative solutions for energy transition
- **Solar energy expertise**
- Continuous work on R&D
- Solutions available through SaaS
- Two main categories:

Forecasting

Monitoring



Installed PV power capacity, 2016



Data source: « Snapshot of Global Photovoltaic Markets »
International Energy Agency, 22 April 2016

The need of PV plant monitoring

- Performance ratio: evaluate the plant condition over time

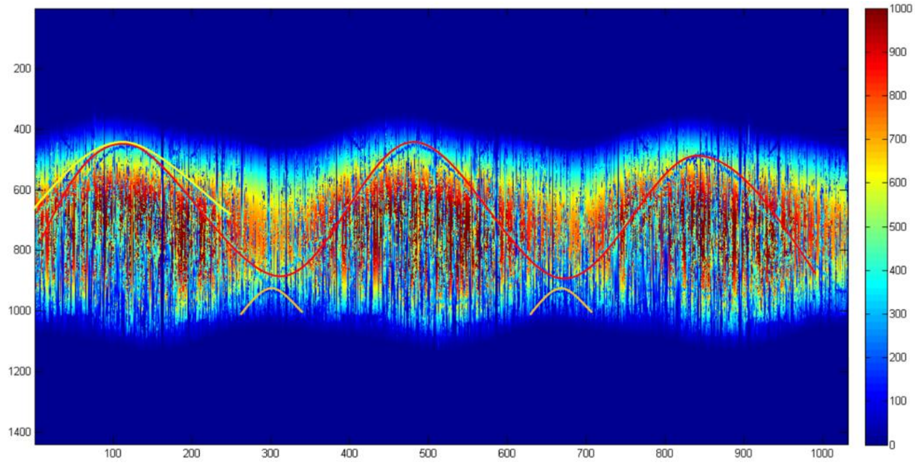
$$\frac{\textbf{Real energy output}}{\textbf{Theoretical energy output}}$$

- Identify the source of losses:
  - Weather: cloudiness, pollution, heat
  - Material damages: aging of the panels, connectors, inverters → **Call for action**

On-site measurement of irradiance

- Basic requirement to evaluate available solar energy
- Instruments are fallible:
  - Material damages, electrical problems
  - Envrionment effect: shadows
  - Drift of the sensor if not regulary calibrated

hours



Irradiance scale (W/m2)

days

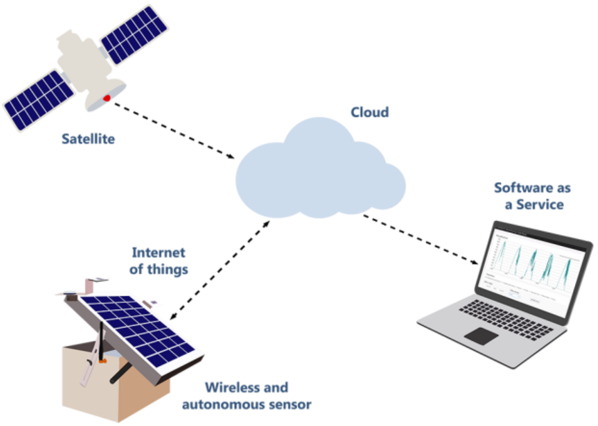
e-SPACE monitoring project

- Improve solar estimation on the ground all over the world with …

Satellite supervision: global coverage, stability of the sensor over time

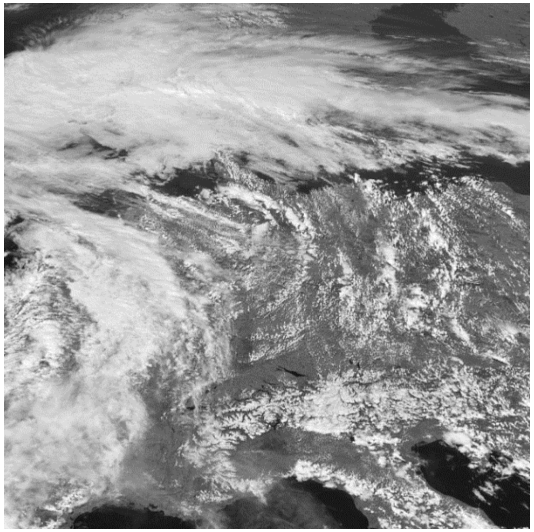
On-site **autonomous and mobile sensors**: local phenomena catcher

… mixed on a GIS and distributed as a service

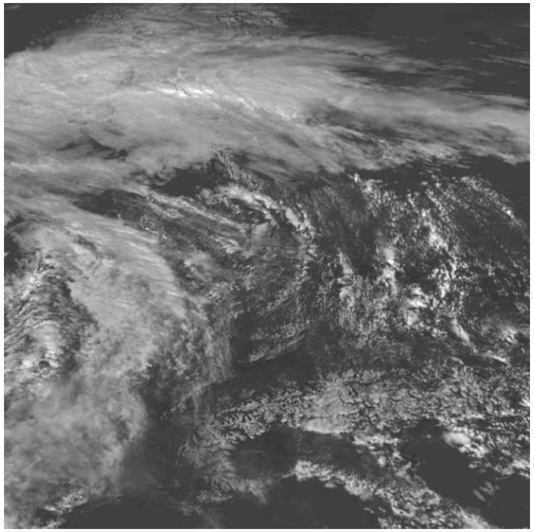


Solar radiation estimation from satellite imagery

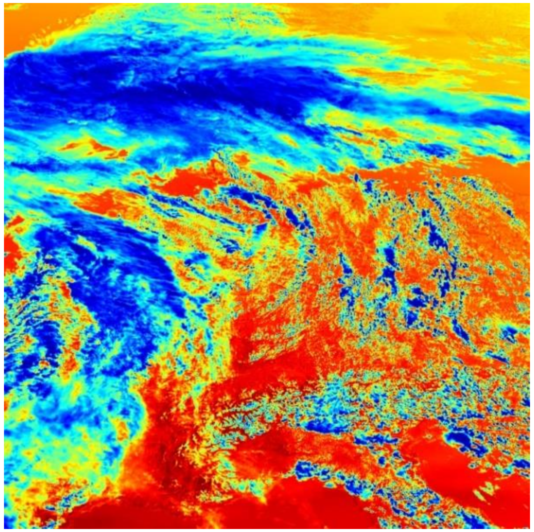
- Reuniwatt's method Sunsat based on Heliosat-2 method



raw image from geostationary satellite



Cloud index: comparison between actual and clear sky for each pixel



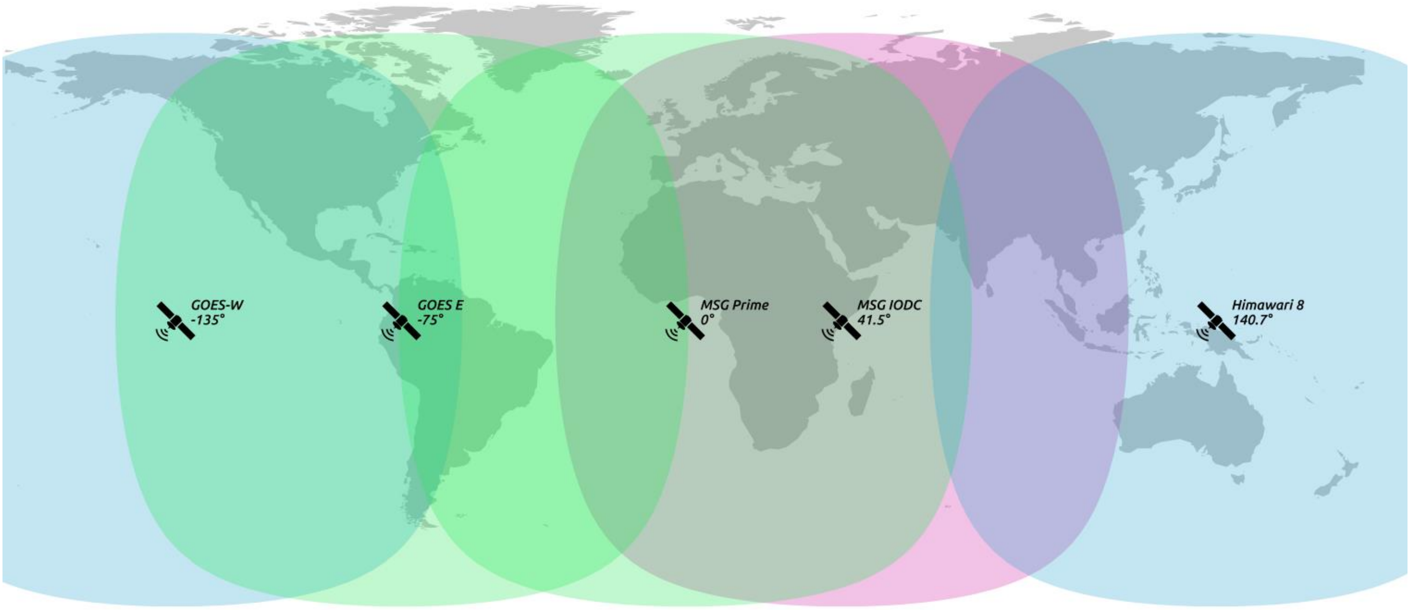
GHI: global horizontal irradiation at ground level

Mines Paristech, Oldenburg University
Rigollier et al. (2004), Cros et al., (2004)

Satellite images

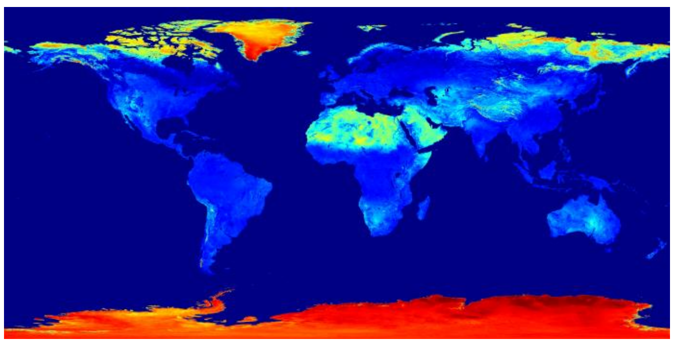
- Geostationnary satellite imagery
  - Cloudiness visibility (visible/IR channels)
  - Regular scans (space and time)
  - Stability of the sensor over time

Satellite	Resolution
MSG Prime	R/PT15M, 1km
MSG IODC	R/PT15M, 1km
Himawari-8	R/PT10M, 500m
GOES-E/W	R/PT15M to R/PT30M, 1km

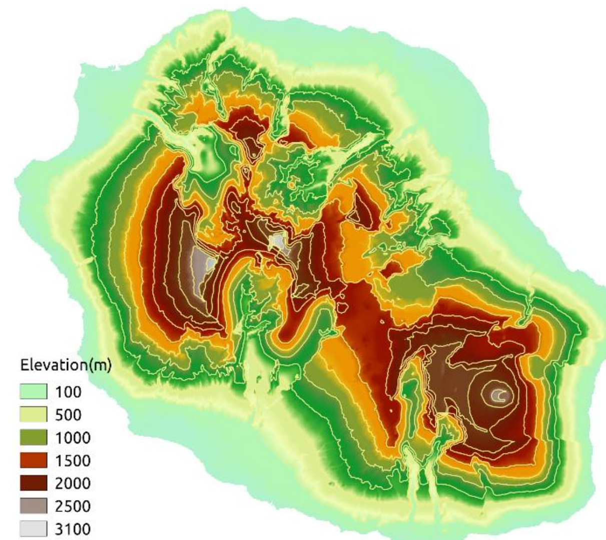


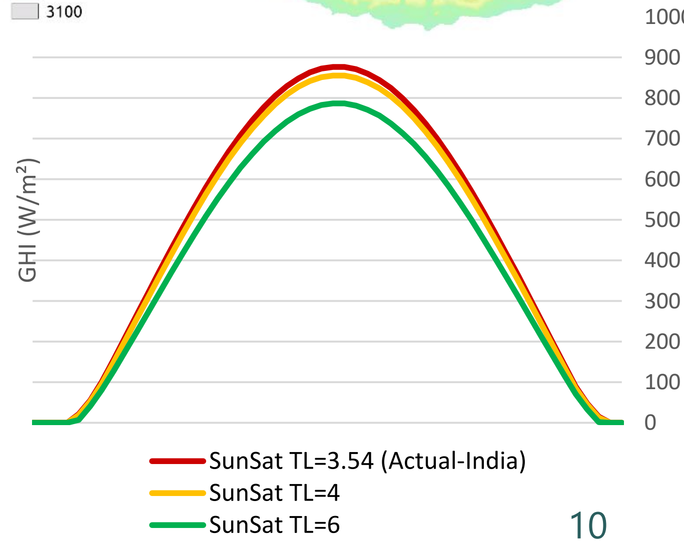
Auxiliary data

- Isolate cloud mask by removing ground **albedo** effect: MODIS products

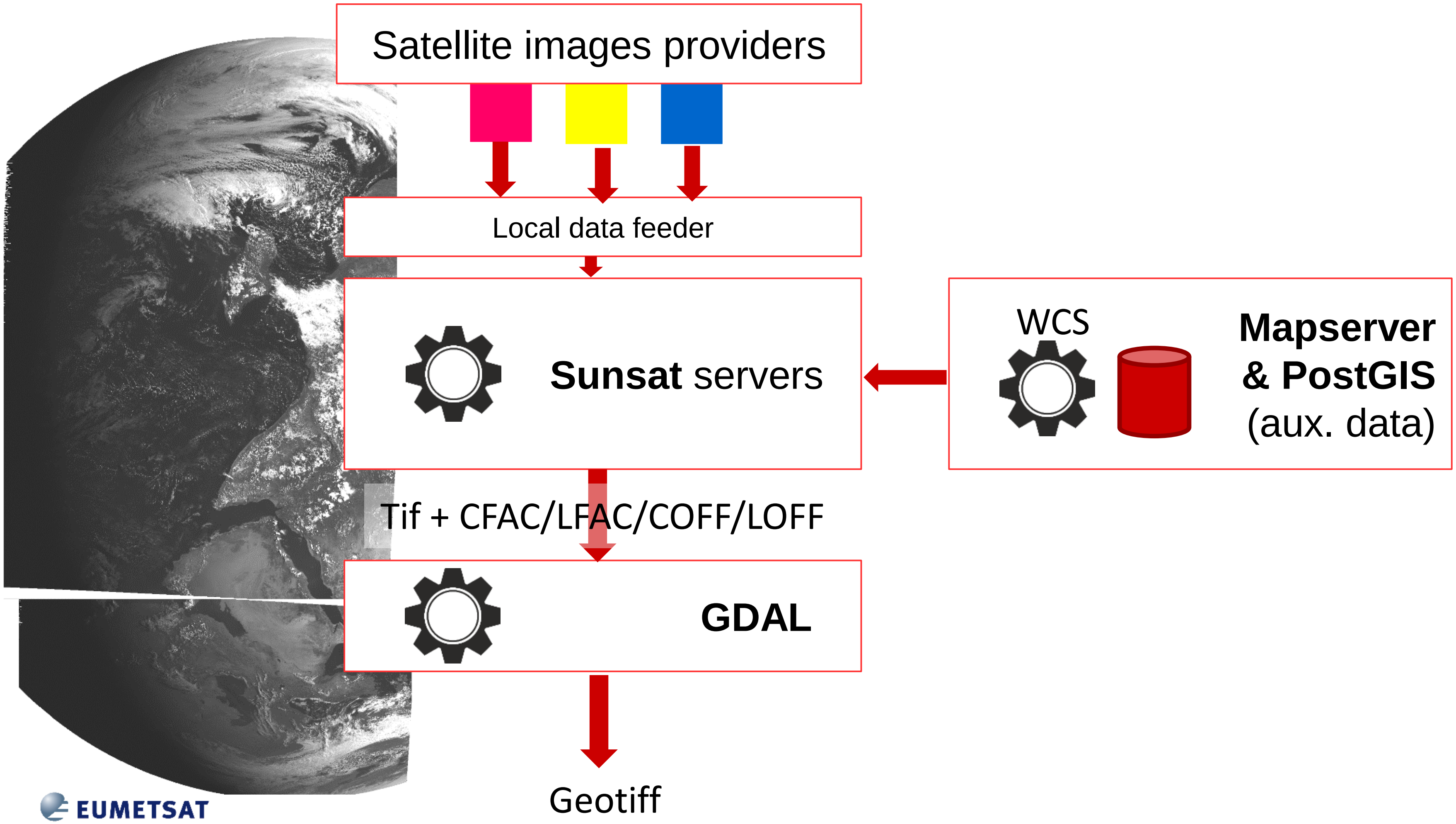


- Calculate ground irradiance using elevation model (**SRTM**) and altmospherical turbidity model (**Linke turbidity**)

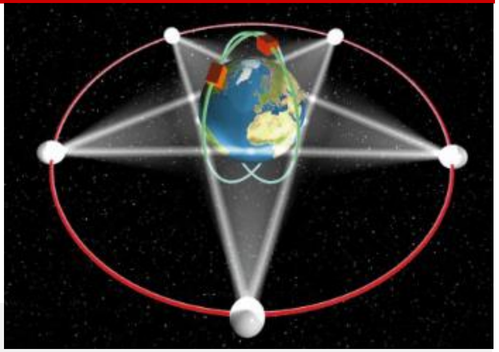




Technical workflow: use of Mapserver, PostGIS, GDAL



Focus on GDAL usage



- Different GEOS projections → unified system WGS84
- Convert pixel/line corners to **geographic coordinates** using geotransform array

h=35785831 # distance center of Earth – satellite

projGeos= « +proj=geos +lon_0=0 +h=35785831 +x_0=0 +y_0=0 +ellps=WGS84 +units=m +no_defs »

GT1= h * 2^16 / CFAC

GT5 = h* 2^16 / LFAC

GT0 = COFF * GT1

GT3 = LOFF * GT5

GT2 = GT4 = 0

→

ulx(geo) = GT0 + GT1* xmin + GT2 * ymin

lrx(geo) = GT0 + GT1* xmax + GT2 * ymax

uly(geo) = GT3 + GT4* xmin + GT5 * ymin

lry(geo) = GT3 + GT4* xmax + GT5 * ymax

gdal_translate –co BIGTIFF=YES –co COMPRESS=DEFLATE –a_srs ${projGeos} -a_ullr ulx uly lrx lry ${file}

gdalwarp –s_srs ${projGeos} –t_srs EPSG:4326 ${file} ${file4326}

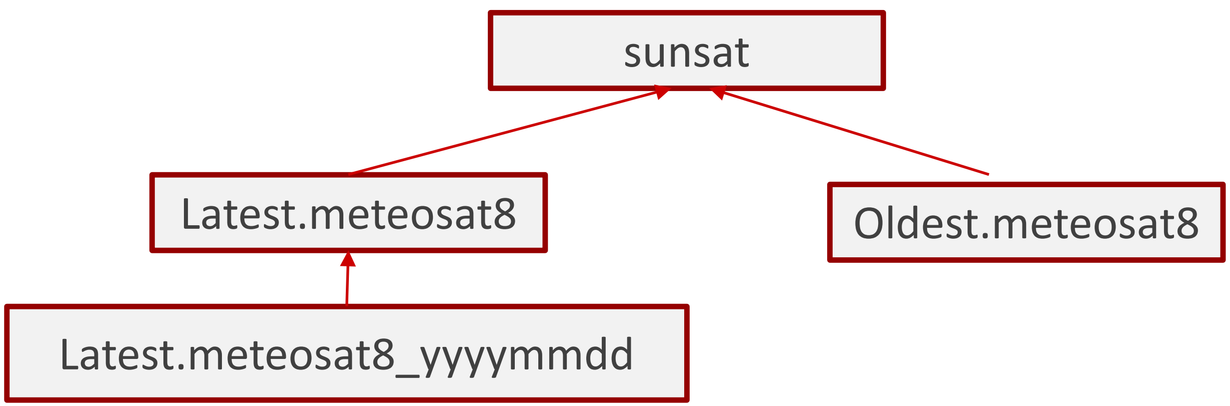
Storage into a scalable database

- PostgreSQL/PostGIS solution (raster2pgsql)

```
# raster2pgsql –t 128x128 –a –N 65535 –F –s EPSG:4326 MSG_2014_04_11_07_00.tif latest.meteosat10
```

- For now: storage of our zones of interest

- Data model thought to be **scalable** and **easy to maintain**: usage of inheritance and schemas (separate real time / historical data)



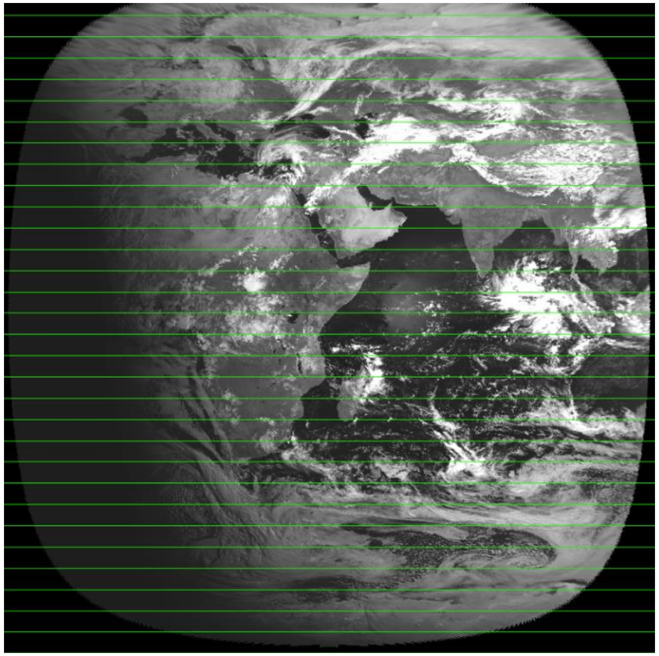
Use of procedural functions

- PL/pgSQL language: ST_MapAlgebra filters
- C functions connexion
- Example: real timestamp of a pixel

End: **2017-04-11T06:42:30**

$$\text{Time } y = \text{start} + 750 * \frac{90\text{-ST\_Y(poi)}}{180} \text{ sec}$$

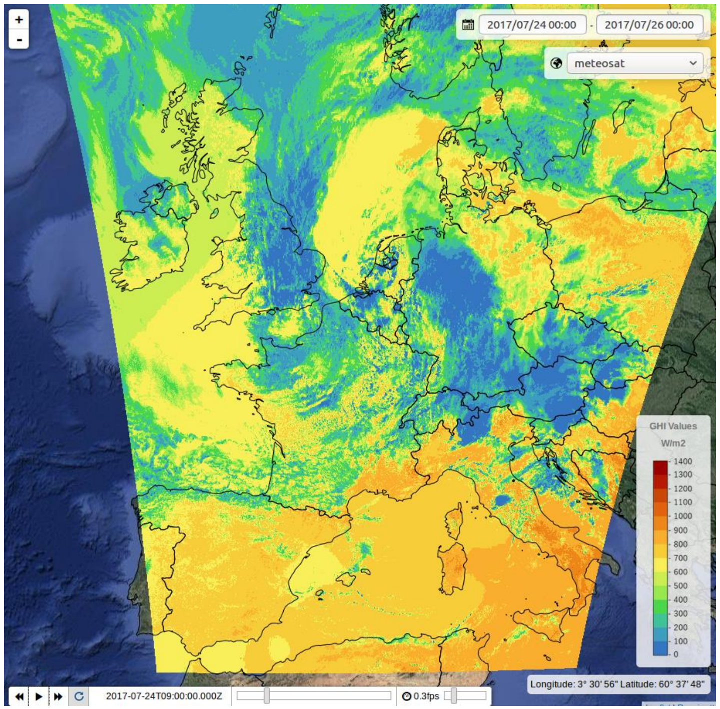
Start: **2017-04-11T06:30:00**



EUMETSAT

Sunsat estimations output

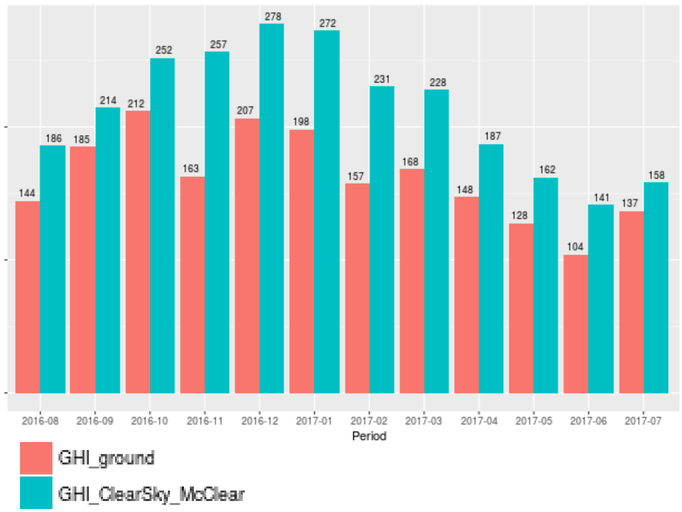
- Time series for analysis
- Up-to-date maps of GHI



Subhourly instant power (W/m2)

↓

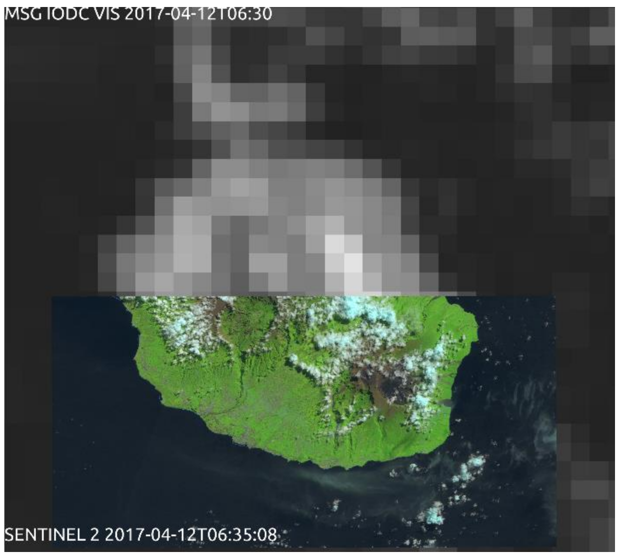
Monthly cumulative energy (Wh/m2/day)



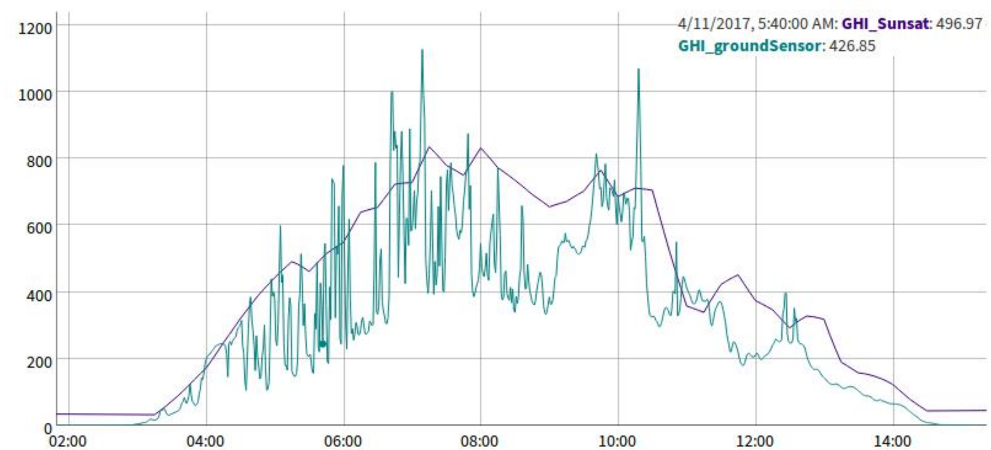
Local phenomena not perceived by satellites

- Satellite imagery performs well for big and stable clouds
- Micro climates not perceived

1km resolution



10m resolution



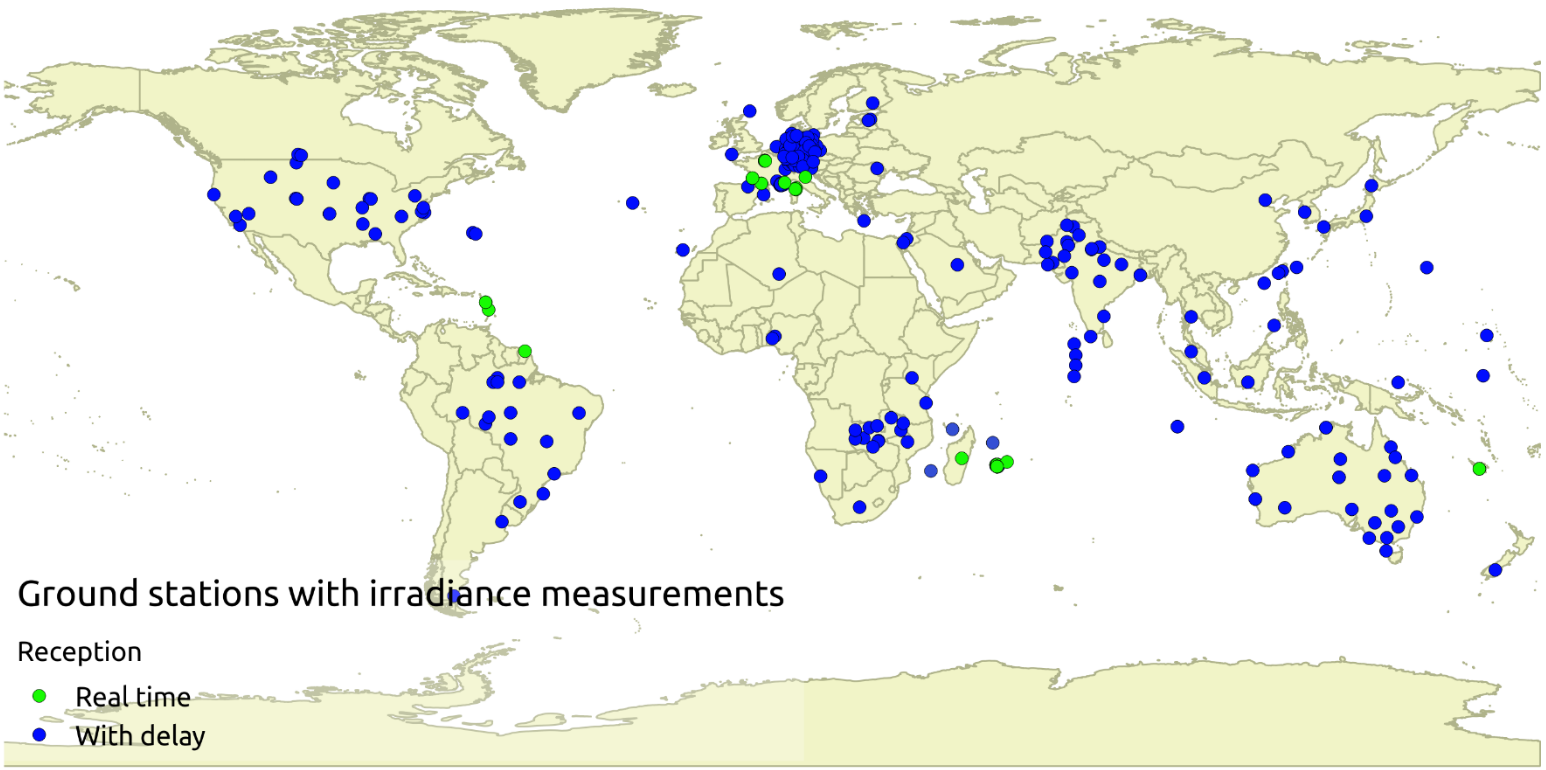
Irradiance ground sensors: local environnement proof

- Different sensitivities and prices of sensors:
  - Pyranometers, pyrheliometers
  - Reference cells
- Reuniwatt bet on a **autonomous**, **easy to deploy** and **low-cost** sensor
  - Irradiance, humidity, temperature
  - Real time observations

Solar InCell

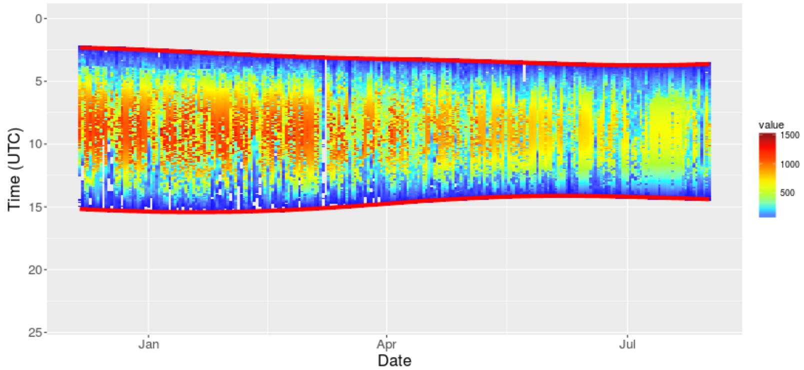
Global network of ground sensors

- Reference networks
- Less qualified but better located sensors



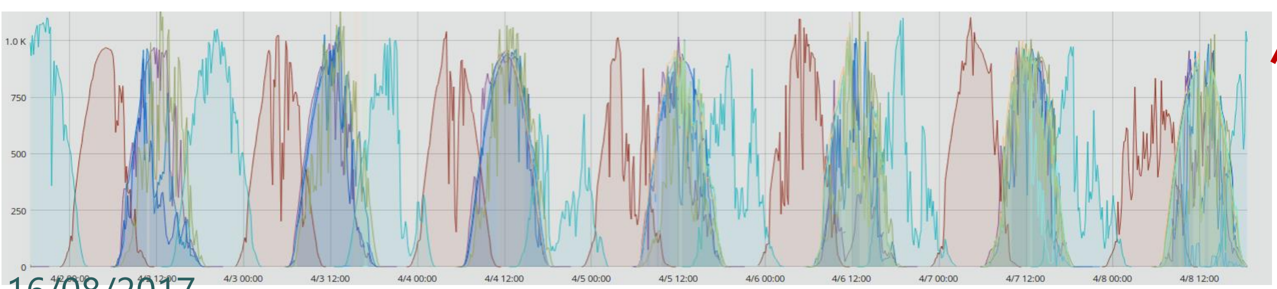
Data processing and storage

- Data quality insurance with R routine
- Storage solutions under testing:
  - Influxdb
  - Warp10 (NoSQL with geolocation)
  - PostgreSQL+PostGIS+timescaledb




```
# create extension postgis;
# create extension timescaledb cascade;
# create table measure (id_site int,timestamp timestamp with time zone,id_variable int,value float)
# create table BSRN() inherits(measure);
# select create_hypertable('BSRN','timestamp');
```

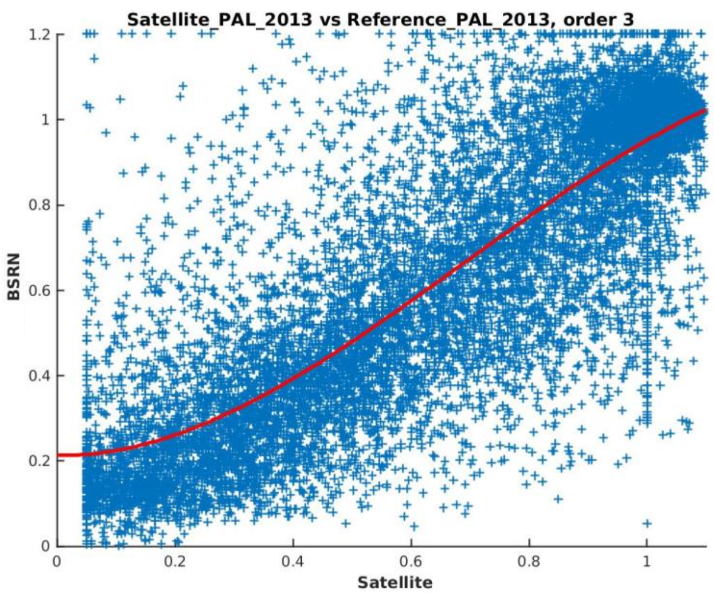
Basic usage of timescale db

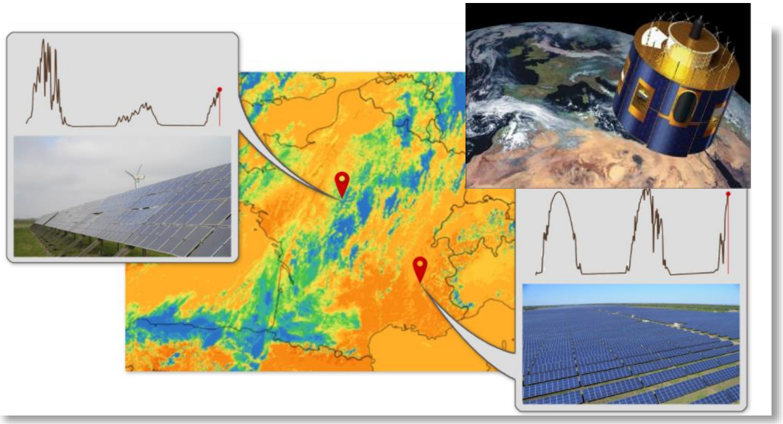


Influxdb + Grafana

Ground sensors refine estimations from satellite

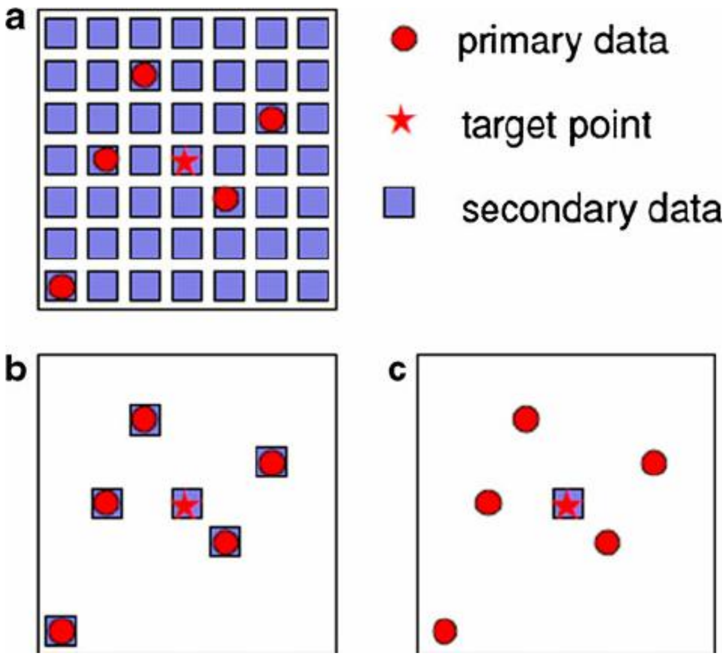
- Empirical method (polynomial regression)
- Require few months of measurements on the point of interest
- Simply apply a correction on historical and actual estimations



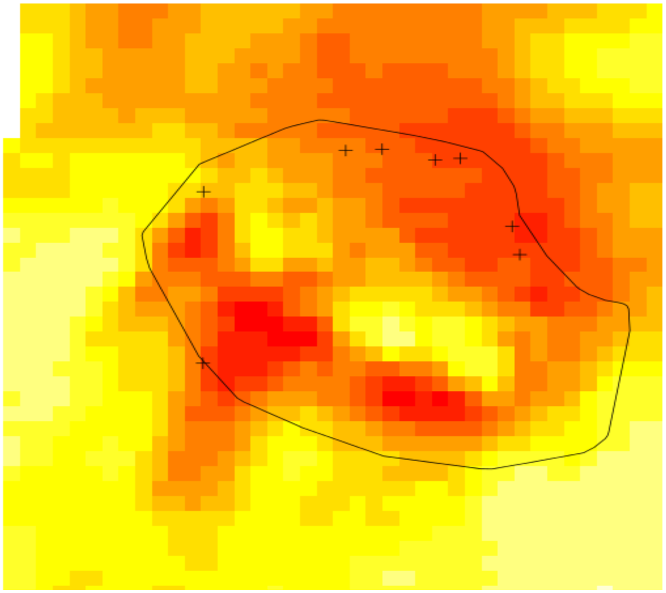


Cokriging for the closest sites

- Refine satellite estimations on a non-instrumented point of interest
- R libraries: raster, rgdal, maptools, gstat, sp

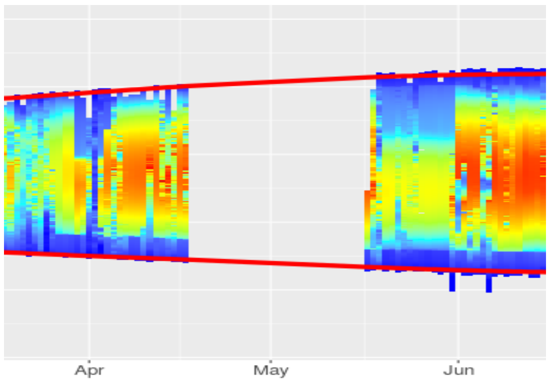


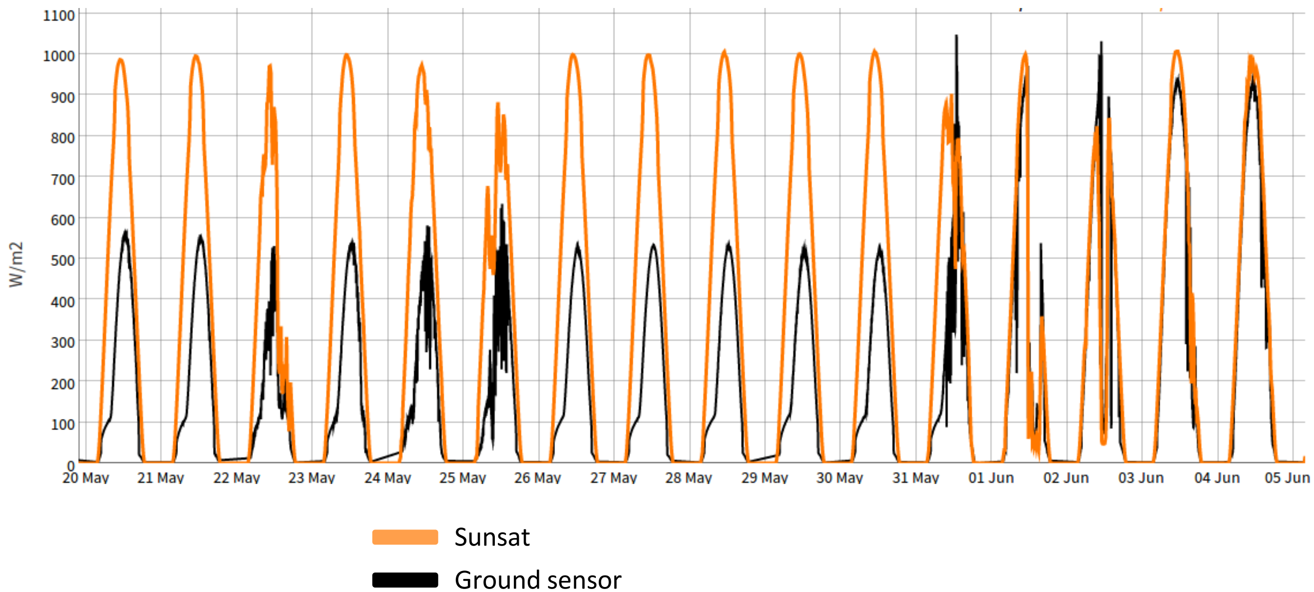
Schematic illustration of cokriging neighborhood configurations: a all data, b multicollocated, and c collocated (Wackernagel 2009)



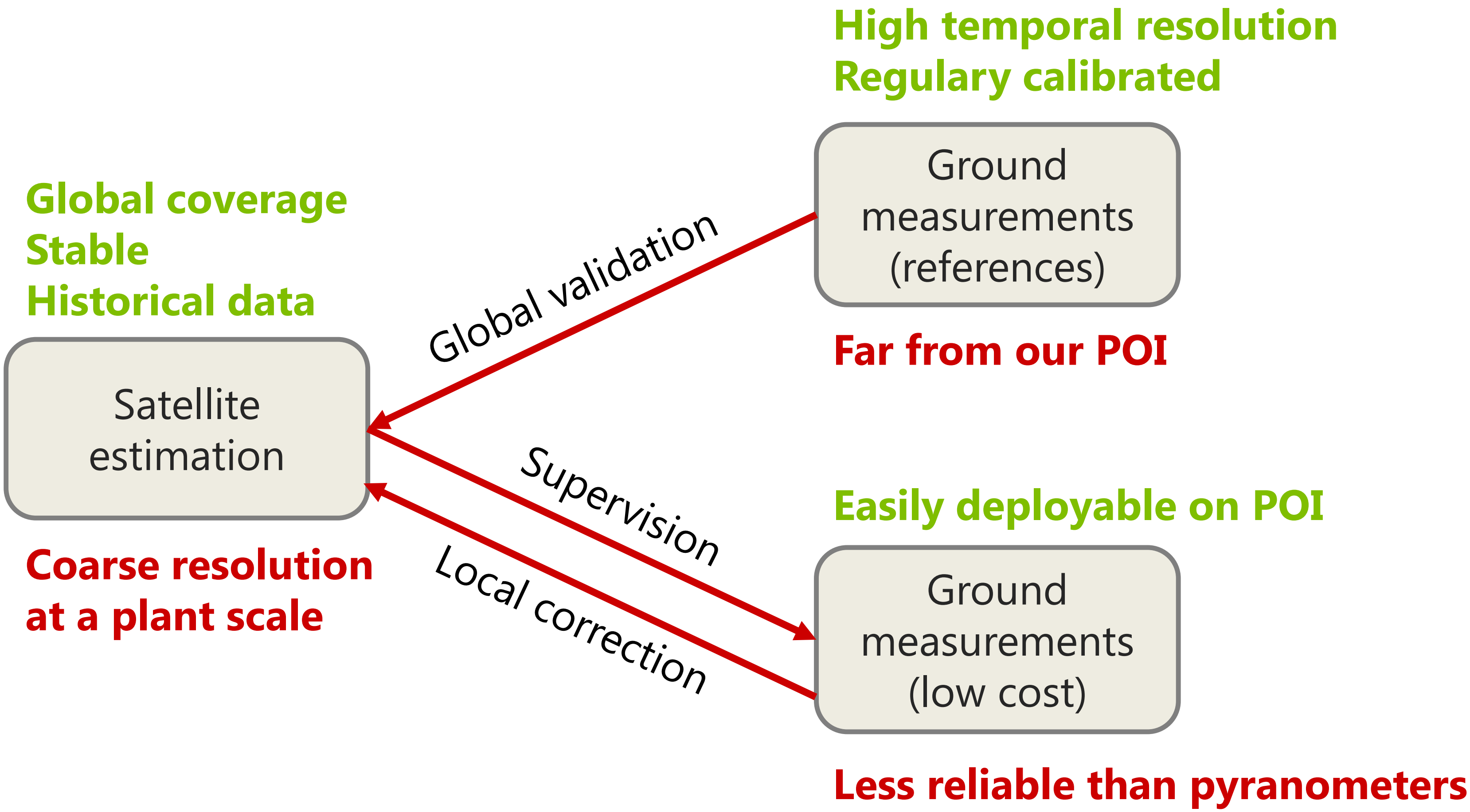
Ensure data quality availability worldwide

- If the sensor is down, satellite data are still available
- Detection of technically possible but obviously wrong measures





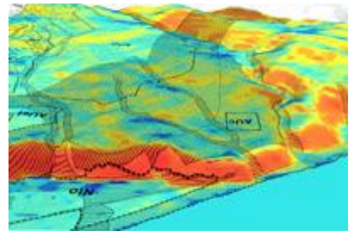
Summary:
the benefits of the mix for irradiance estimation



Complex back-end to a user-friendly front-end

- Complex back-end: data collection from different sources, processing and homogenization, storage and distribution
- Possible with **OSGEO solutions** (GDAL, Mapserver, PostGIS,...)
- Served to the client through a user-friendly interface (shiny app)

Reuniwatt



Thank you

FOSS4G 2017, Boston

e-SPACE monitoring

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