Solar Atlas

Provence-Alpes-Côte d'Azur

High Spatial Resolution Solar Atlas In Provence-Alpes-Côte d'Azur

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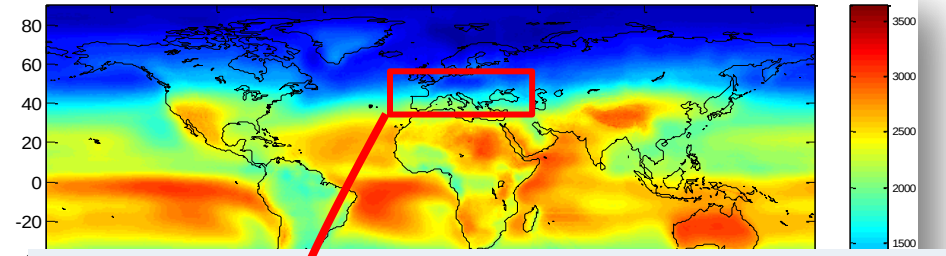
RAPID TRANSITION TO A RENEWABLE ENERGY WORLD

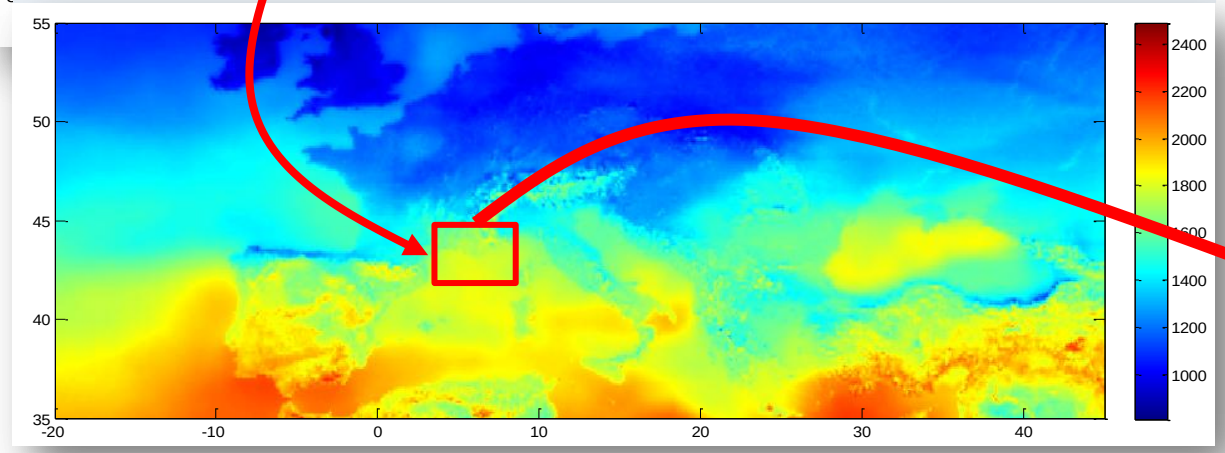
Introduction

Cartography of Solar Resource at different scales

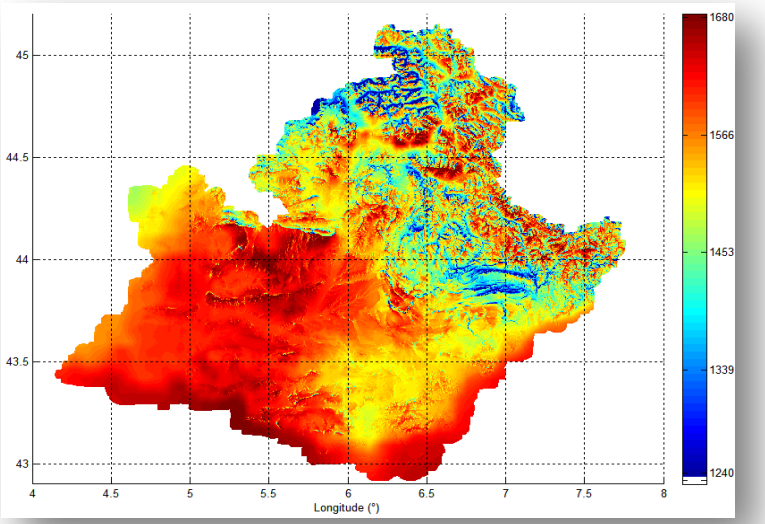
Worldwide yearly sum of global horizontal irradiation map (kWh/m^2) from NWP re-analysises (res. ~ 50 km)



Yearly sum of GHI map (kWh/m^2) for Europe from HelioClim databases
(res. ~5 km, method Heliosat-2 applied to Meteosat images)



High resolution yearly sum of GHI map (kWh/m^2) for the region Provence-Alpes-Côte d'Azur (res. 200 m)



Introduction

- **Project (realized in 2010)**
  - Co-funding: Provence-Alpes-Côte d'Azur (PACA) region, ADEME PACA
  - Co-funding: Council of the Department "Alpes Maritimes"
  - Supported by CAPENERGIES: competitiveness cluster for Energy in PACA
- **Main characteristics:**
  - Based on HelioClim-3 satellite-based surface solar irradiation database (based on Meteosat Second Generation: res. ~ 4 km, near real-time from 2004)
  - 200 m resolution solar maps
  - Monthly and yearly sum of Irradiations
    - Long-term mean and (standard deviation)
    - Time series of monthly and yearly irradiations
  - PV and Solar Thermodynamic Applications
    - Global irradiations on typical tilted plans (*e.g.* for PV, thermal systems)
    - Direct Irradiation on typical tilted plans and in normal incidence (*e.g.* for CSP and CPV)

Introduction

- **The potential end-users of the solar atlas:**
  - Governmental and private actors
    - Geographical analysis of local solar potential
    - Sitting and sizing solar power plants
      Advanced feasibility pre-studies based on geographical analysis (before, for example, the local installation of a pyranometer station)
  - Individual
    - High resolution map suitable for sizing small individual solar systems (small PV system, solar water heating systems, etc)
    - Accurate and well-presented solar maps are concrete and instructive for everybody (e.g. education) to promote solar energy

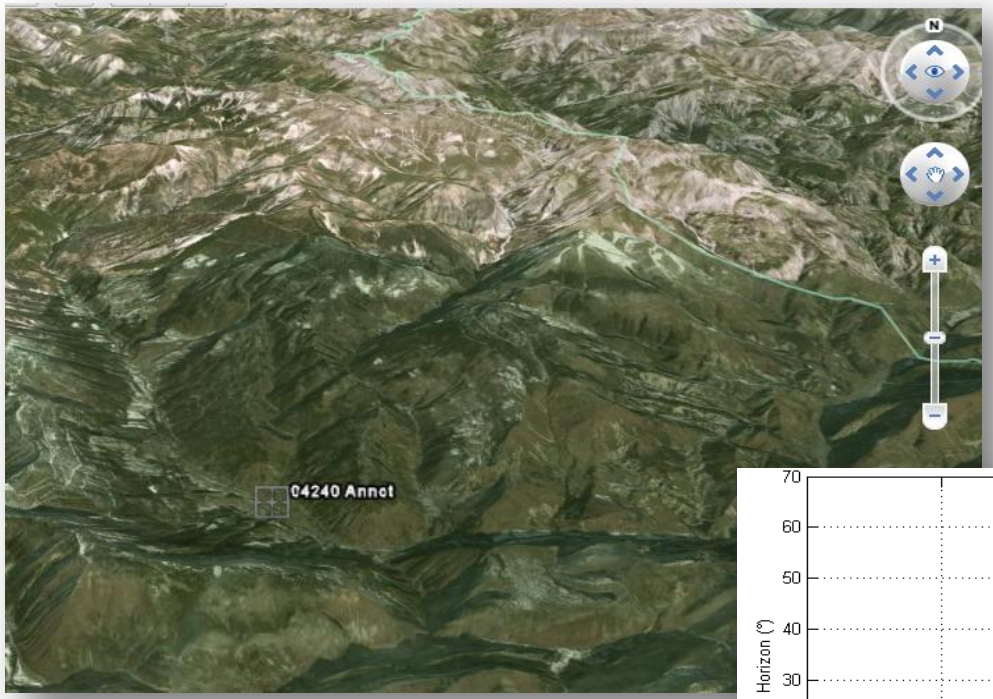
Increase the spatial resolution of HelioClim-3

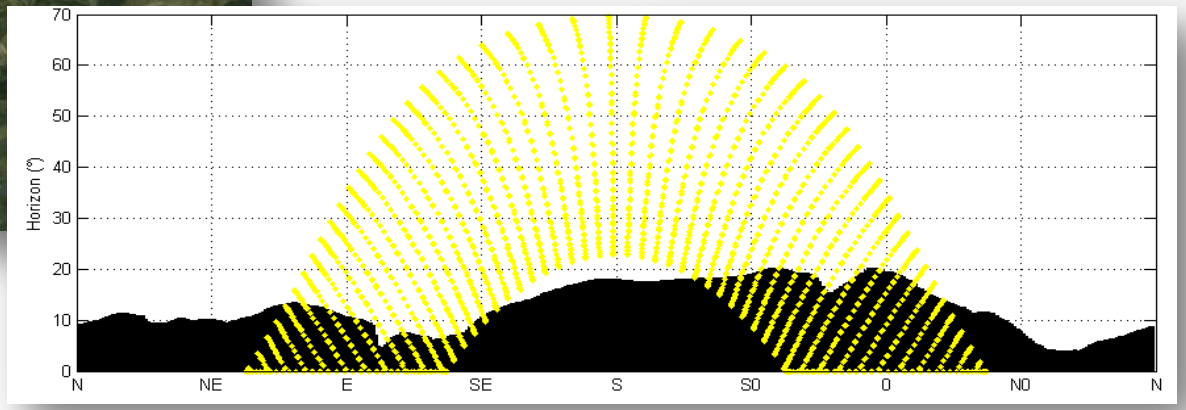
- **Intra-pixel (HC-3) effects of the relief**
  - Use of the relief database SRTM (Shuttle Radar Topography Mission)
    - Spatial resolution of 100 m
    - Localization Accuracy better than 10 m
  - Effect of the optical depth variations of the atmosphere (Abdel Wahab et al., 2008)
  - Shadow effects respectively for the diffuse and direct components of the global irradiation (Ruiz-Arias et al., 2010)

- **Local calibration of irradiation estimation with on-ground pyranometric measurements**
  - Calibration of the global horizontal irradiation (GHI)
  - Calibration of the parametric experimental model of global/diffuse decomposition
  - Modeling of uncertainty from the calibration residue analysis

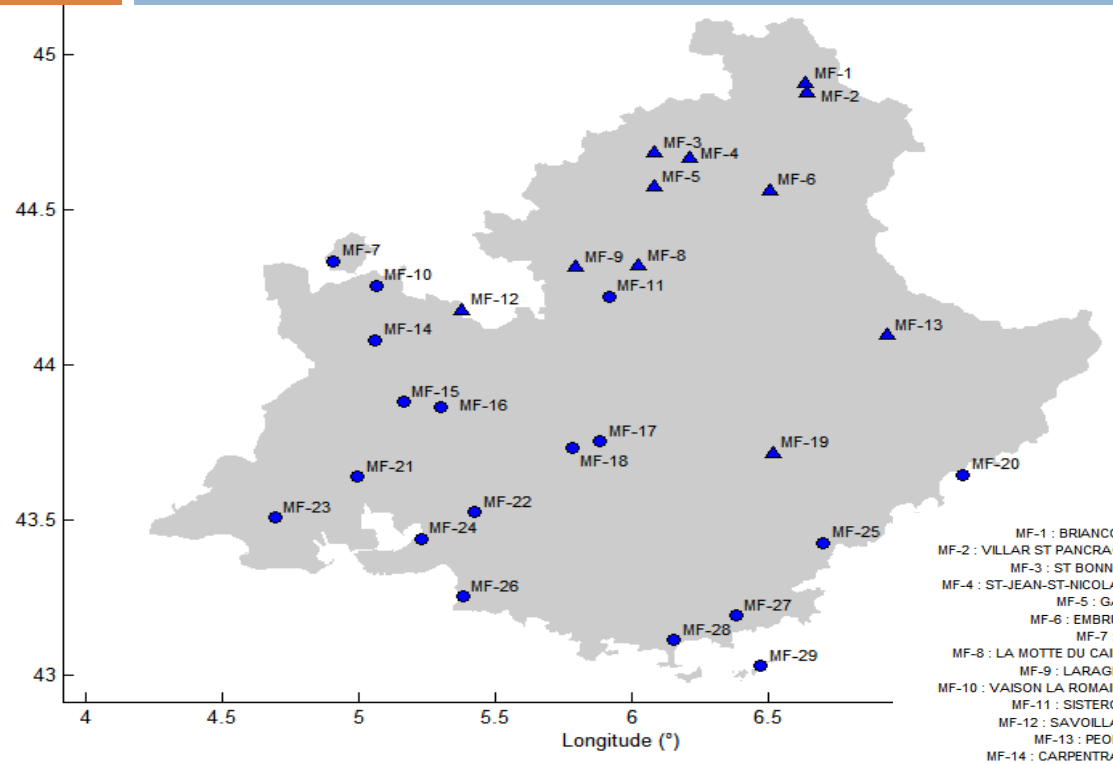
Shadows effects on solar irradiation

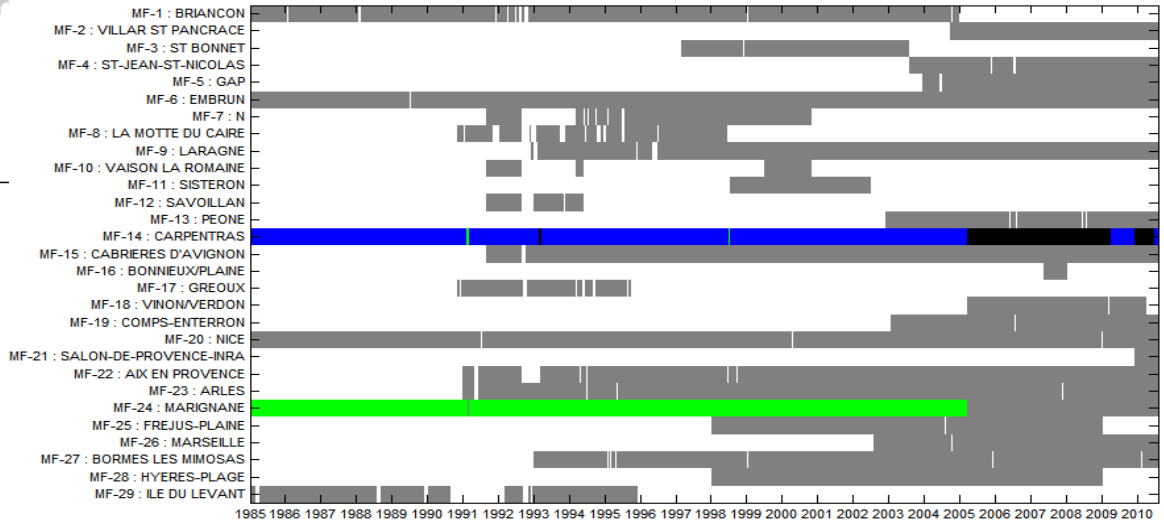
Example : Annot





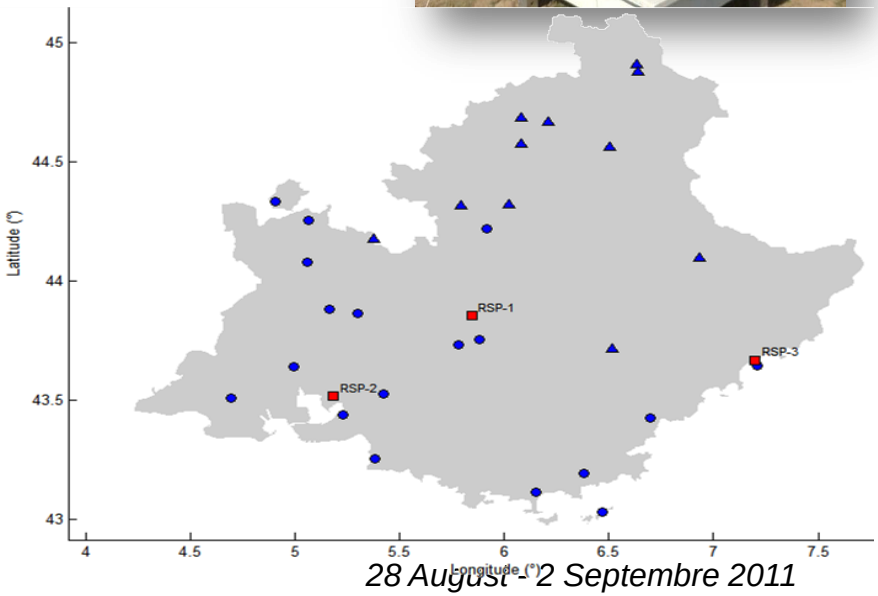
The meteorological stations (Météo France) for the calibration





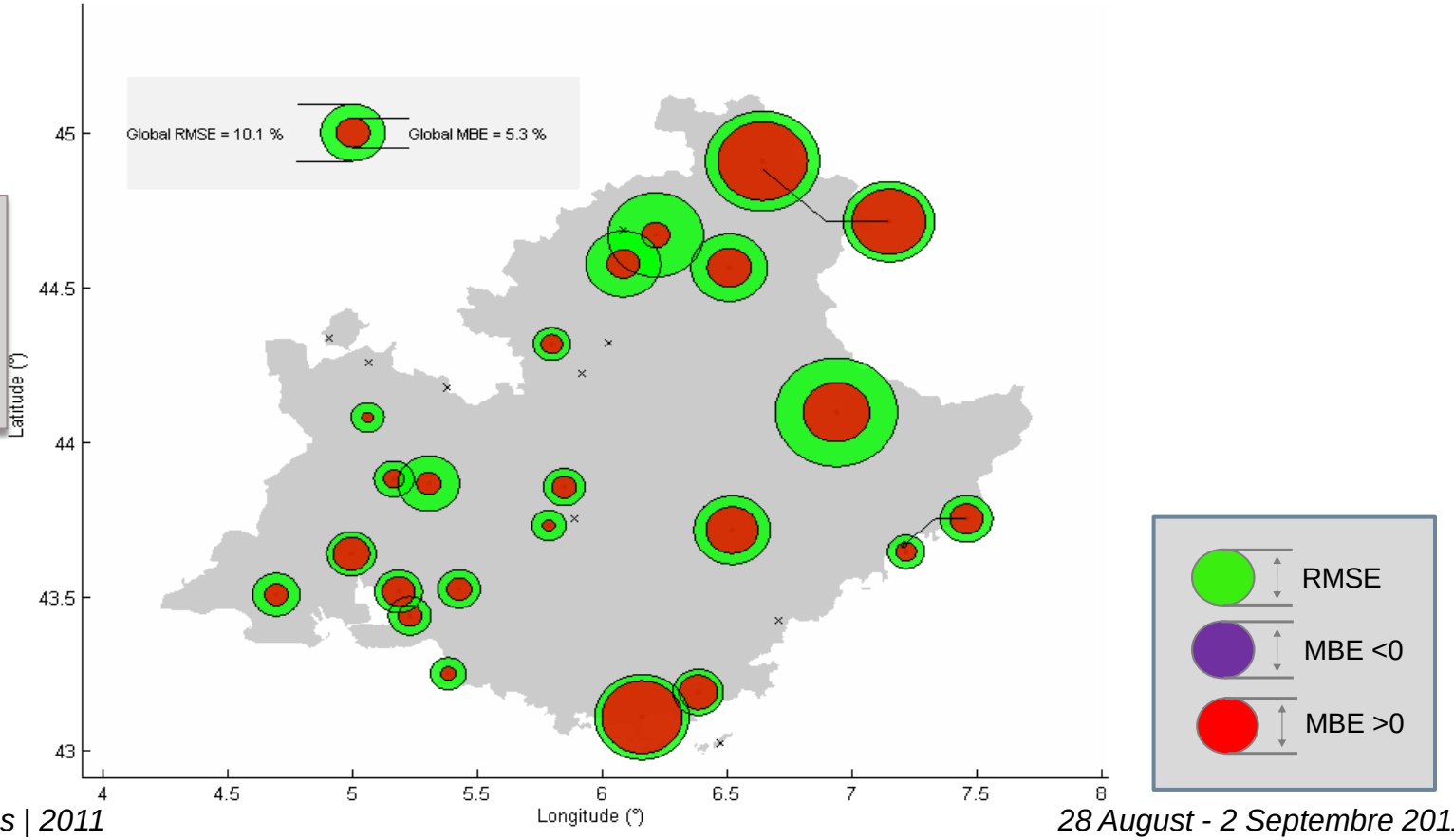
The meteorological stations for the HelioClim calibration

- **The three meteorological stations for the project (RSP)**
  - One year renting (CSP Service) (spin-off of the German Aerospace, DLR)
  - global and diffuse irradiations on horizontal plan (sampling : 10 min) (+ temperature and humidity)
  - RSP : accurate system and robust with respect to
    - dust
    - misalignments



« Raw* » HelioClim-3: monthly GHI estimation errors

	NDATA	MREF	MBE	MAE	RMSE	CC
Monthly sums of GHI (Reference: MF stations)	1269 months	132.2 kWh/m^2	5.3 %	7.5 %	10.1 %	0.992



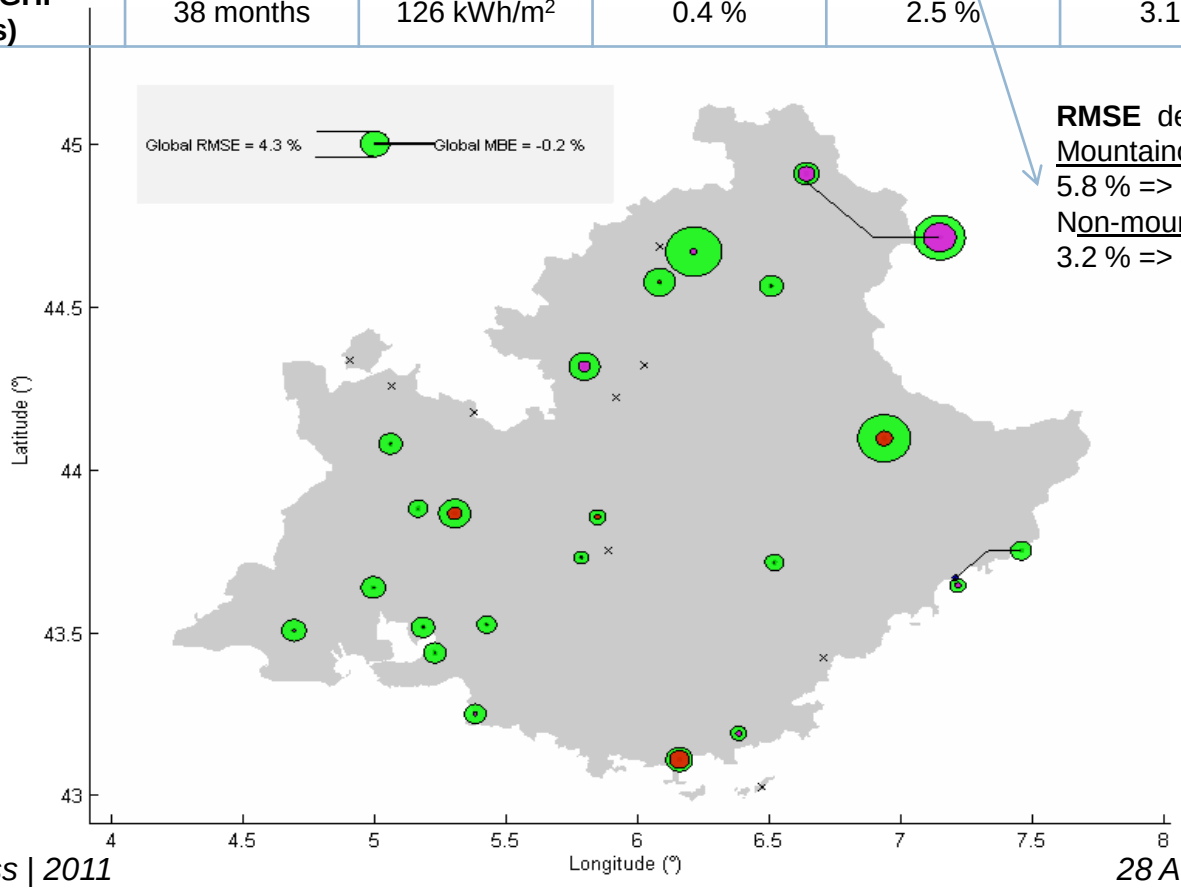
** "Raw" HC3:*
- *No correction of orography effects*
- *No local calibration*

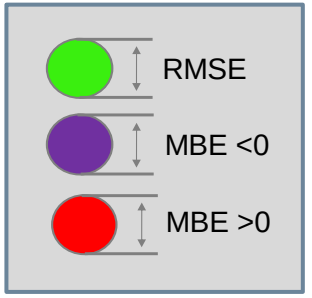
Corrected* HelioClim-3: monthly GHI estimation errors

	NDATA	MREF	MBE	MAE	RMSE	CC
Monthly sums of GHI (Ref: 20 MF stations)	1269 months	132 kWh/m^2	-0.2 %	3.1 %	4.3 %	0.996
Monthly sums of GHI LOOCV (Ref: 20 MF stations)	1267 months	132 kWh/m^2	-0.7 %	4.4 %	6.2 %	0.991
Monthly sums of GHI (3 RSP stations)	38 months	126 kWh/m^2	0.4 %	2.5 %	3.1 %	0.998

RMSE dependency with orography
Mountainous area:
5.8 % => 7.4 kWh/m^2 (et MBE = -0.6%)
Non-mountainous area:
3.2 % => 4.3 kWh/m^2 (et MBE < -0.1%)

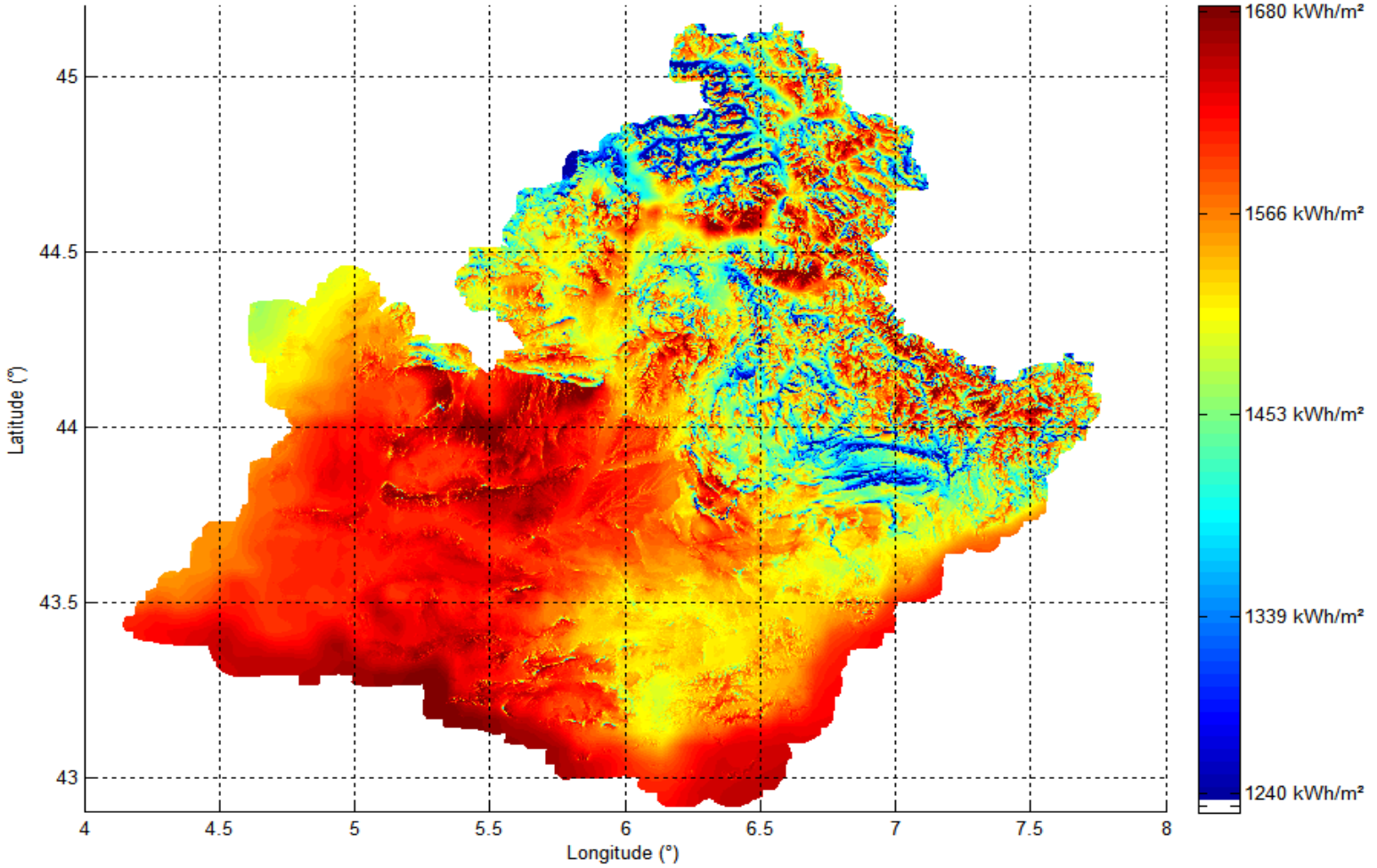
* ***Corrected HC3:***
- *Orography effects*
- *Local calibration*





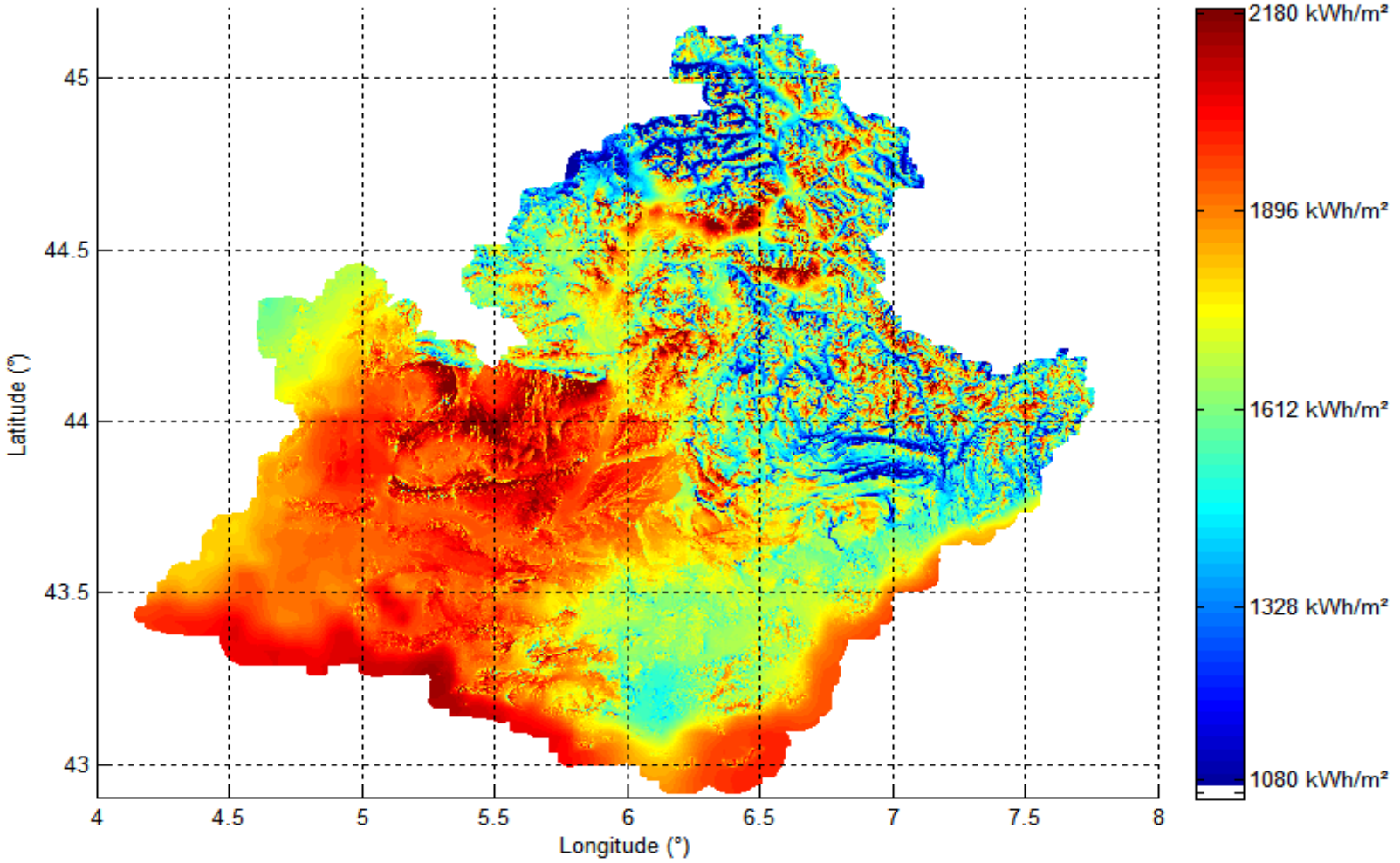
Example of high resolution irradiation map

Map of yearly sums of GHI (mean between 2004 –2010)



Example of high resolution irradiation map

Map of yearly sums of DNI (mean between 2004 –2010)



Dissemination of the solar atlas

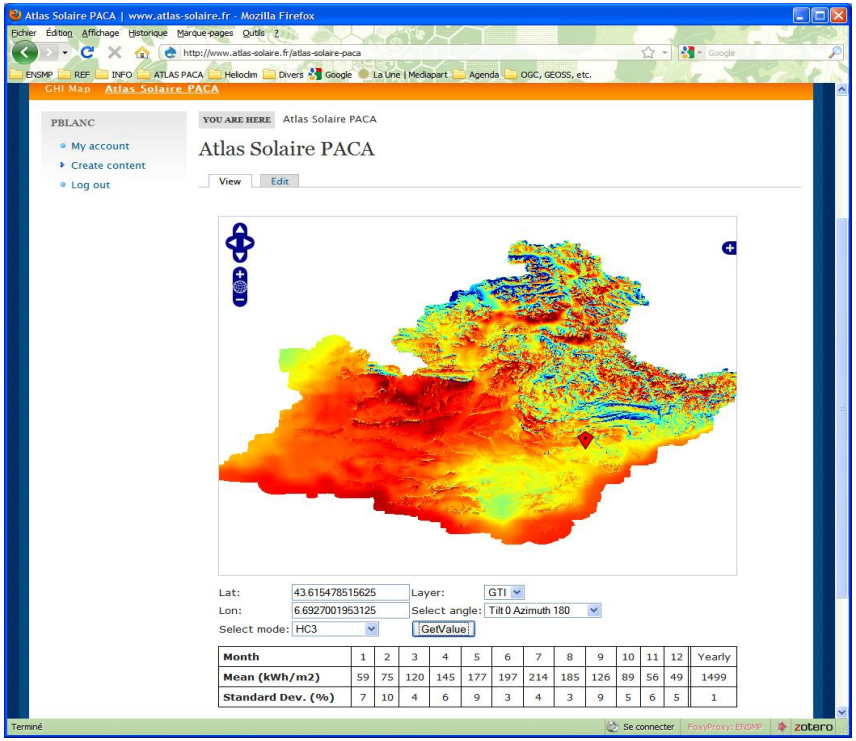
Web Map Services (OGC)

- « MapServer » web address
  www.webservice-energy.org/mapserv/atlas_paca_v1.0_beta

- Different clients for visualization or exploitation
  - Google Earth (WMS: client implemented)
  - WEB GIS clients
    - GEO-PORTAL http://www.geoportal.org
    - The GIS of the french department of ecology CARMEN http://carmen.ecologie.gouv.fr/
  - GIS software (*e.g.* the freeware Quantum-GIS)

Dissemination of the solar atlas

- **Specific Web Service**
  - Means of monthly sum of irradiations at a given geo-location
    http://www.atlas-solaire.fr



Conclusion

- **High resolution Solar Atlas**
  - Resolution: 200 m
  - HelioClim-3 database (res. 4 km, period: 2004 - 2010)
  - Shadow effects estimated from the DEM SRTM
  - Local calibration with ground pyranometric stations
  - Monthly sum of global and direct irradiation on different tilted plan
  - Uncertainties estimated from statistical analysis of the calibration residue w.r.t. pyranometric ground stations
    - Monthly sum of global irradiation: bias < 1 %, RMSE ~ 5 % (~7 kWh/m^2)
    - Monthly sum of direct normal irradiation: bias < 1 %, RMSE ~8 % (~12.5 kWh/m^2)