MESOR TRAINING SEMINAR

PART 3:

Overview on Solar Resource Products

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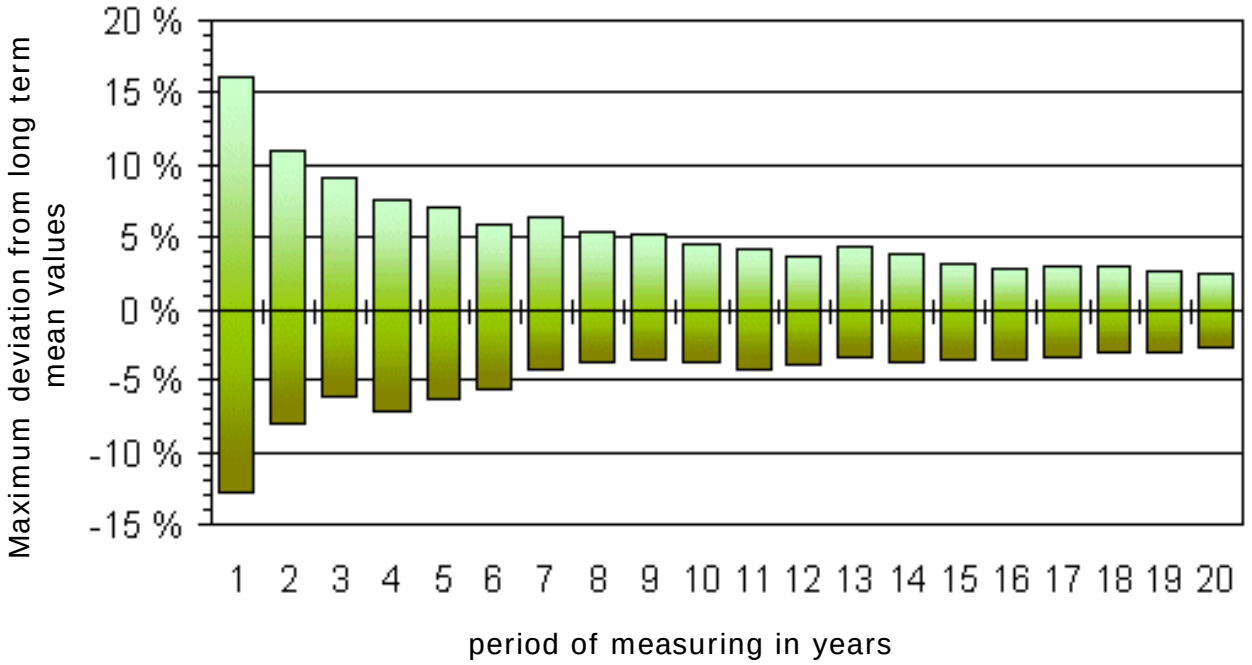
Overview

- sources of irradiance information
  - ground measurements
  - satellite data
  - reanalysis of numerical weather prediction models and climate models
- overview on resource products

Representative historic data -> long-term time series

period large enough to account for seasonal and inter-annual variability

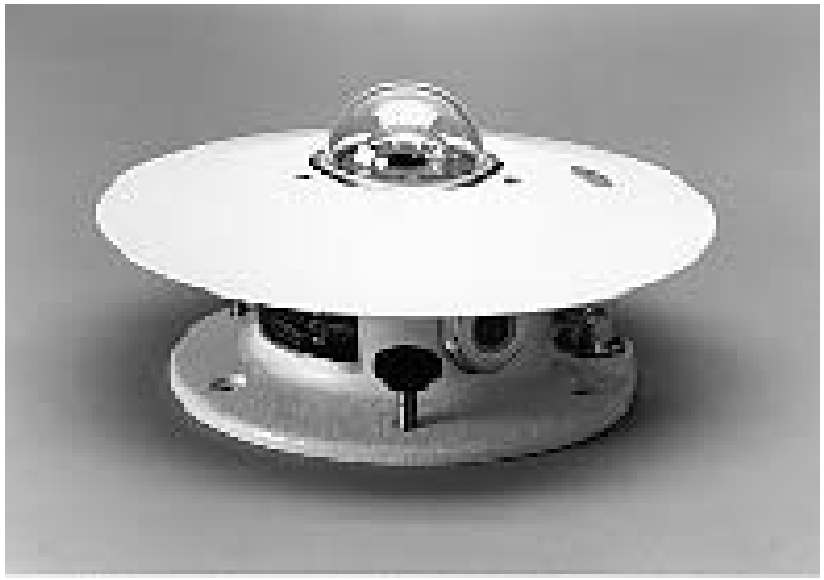


Meteorological station at Potsdam, 1937- 1999 (source: Quaschning, 2001)

Solar radiation instruments

global irradiance

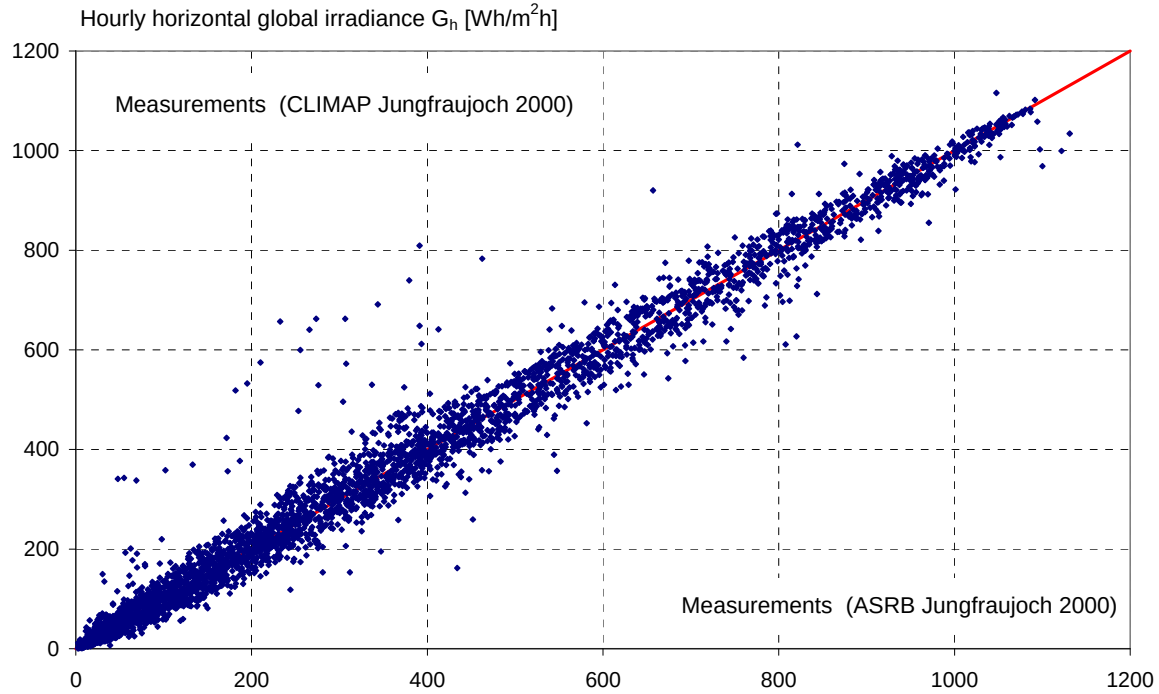
- pyranometer:
  uncertainty: 2%* – 5%
- reference cells:
  uncertainty: 5% – 10%



*target accuracy of Baseline Surface Radiation Network (BSRN)

Side by side comparsion: Junfraujoch station

- ASRB station and CLIMAP station (MeteoSwiss)
- comparable GHI with 12% dispersion (42 Wh/m^{2}h)
- comparable DNI with very high dispersion (extrem conditions)



Solar radiation instruments

diffuse irradiance

shaded pyranometers

- pyranometer with shading ring
- pyranometer with shading disc and sun tracking device
  uncertainty: 4%*- 8%

*target accuracy of Baseline Surface Radiation Network (BSRN)

Solar radiation instruments

direct irradiance

- field pyrheliometer
- absolute cavity radiometer (current world reference of calibration)
- combined measurements uncertainty: 1%*
- rotation shadowband pyranometer uncertainty: 2%

*target accuracy of Baseline Surface Radiation Network (BSRN)

Availability of ground measured data

long term measurements at meteorological stations

- National Meteorological offices
- World radiometric Network (by World Meteorological Organisation)
- Baseline Surface Radiation Network

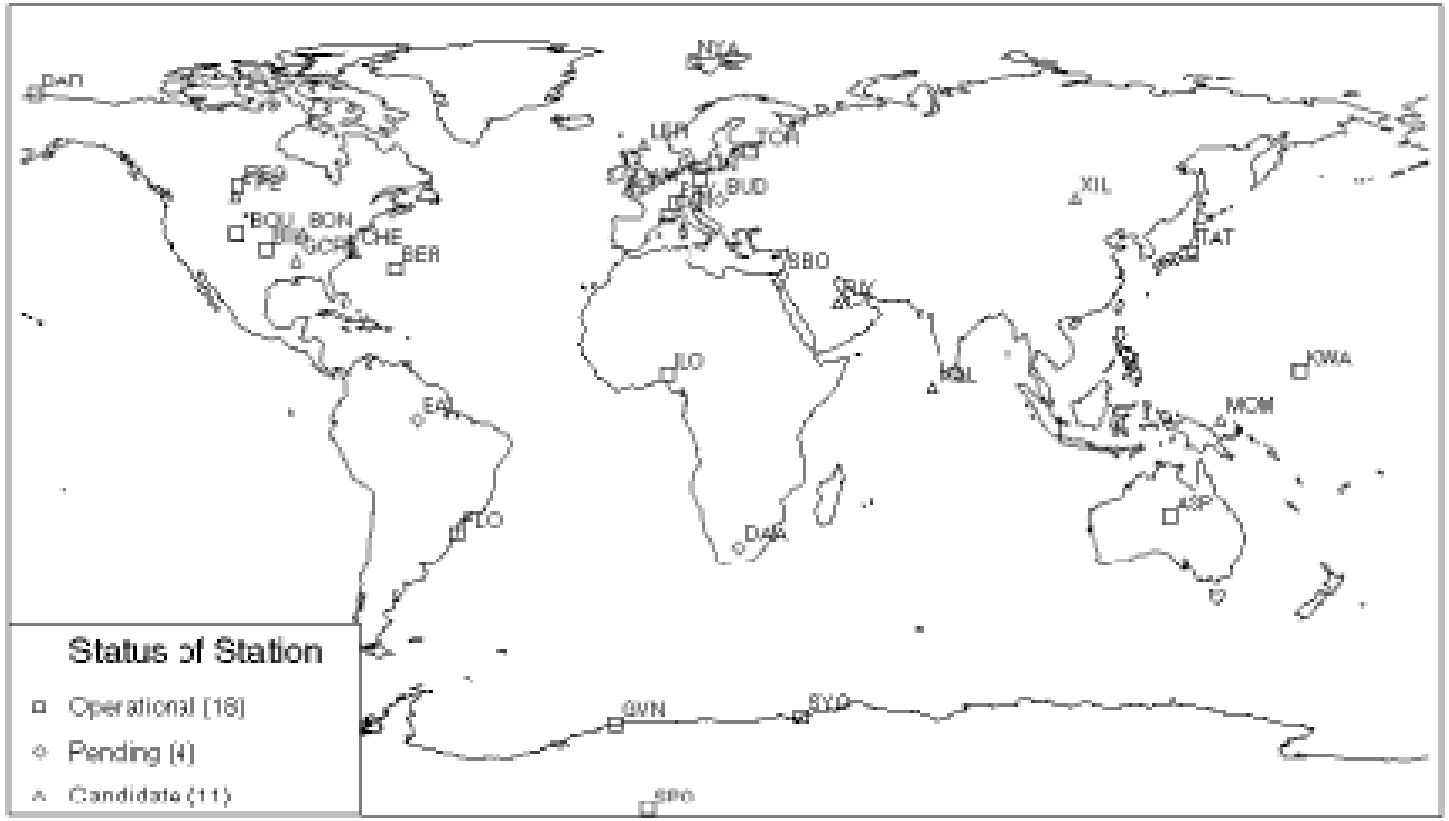
World radiometric network

- global irradiance & sunshine duration
- ca. 1200 stations

World Radiometric network 1966- 1993
(source: WRDC/WMO, Cros et al. , 2004)

Baseline surface radiation network

- high quality measurements
- global, direct, diffuse
- minute values



source: Cros et al., 2004

Ground measured data

advantages and limitations

- **high quality** of data (for well maintained stations)
- **high effort & cost** for maintenance of stations
- **spatial coverage** of available long term measurements **is coarse**
- spatial distribution of stations is **heterogeneous**

Resource products based on ground measured data

- **spatial interpolation techniques** to derive maps and site specific data
- **stochastic models or average daily profiles** to obtain values with high temporal resolution (daily, hourly or minute values)
- **global to beam models** to infer DNI

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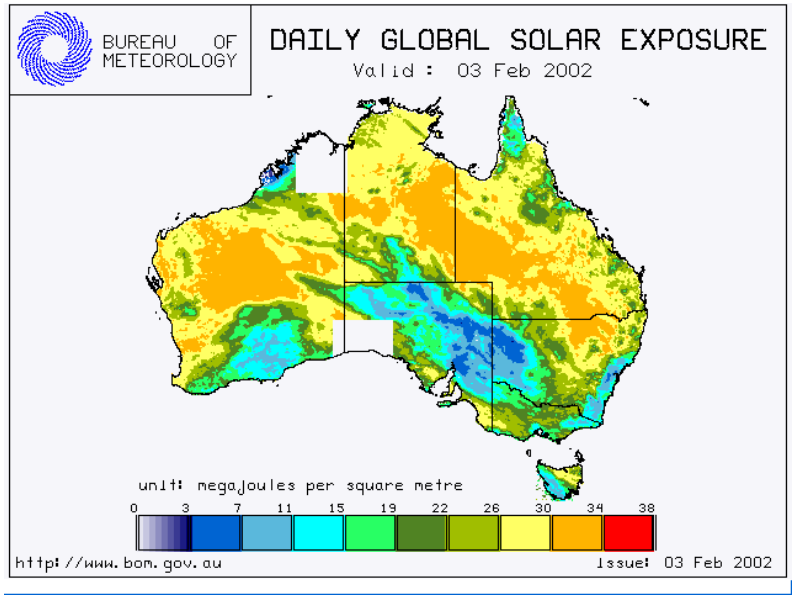
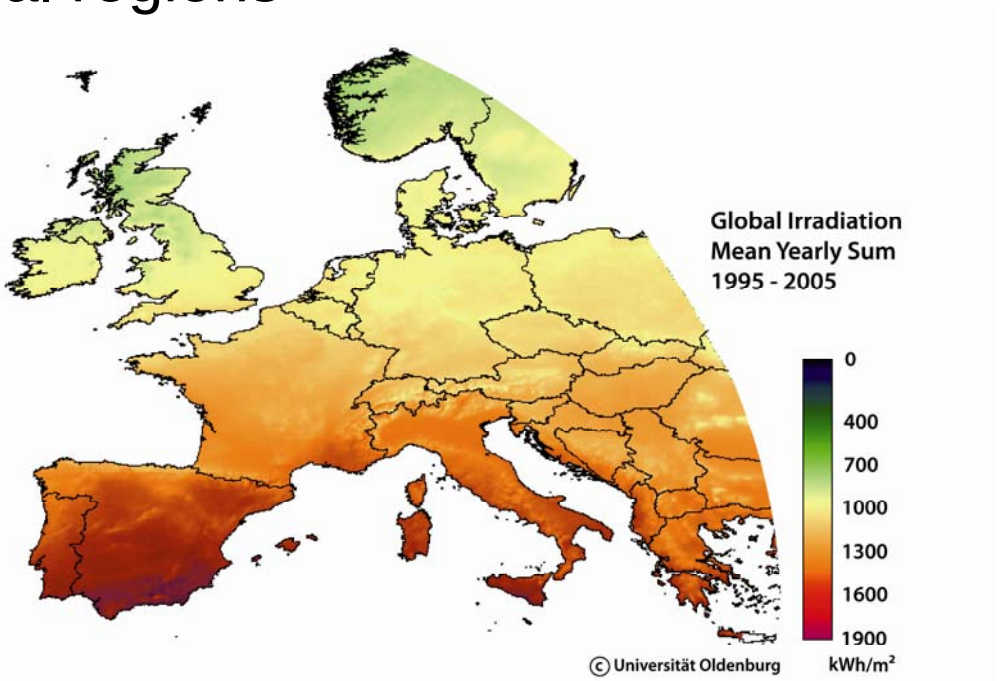
Irradiance from satellite data

advantage: available with high temporal and spatial resolution for large geographical regions



example output of Australian Global Solar Radiation Archive server

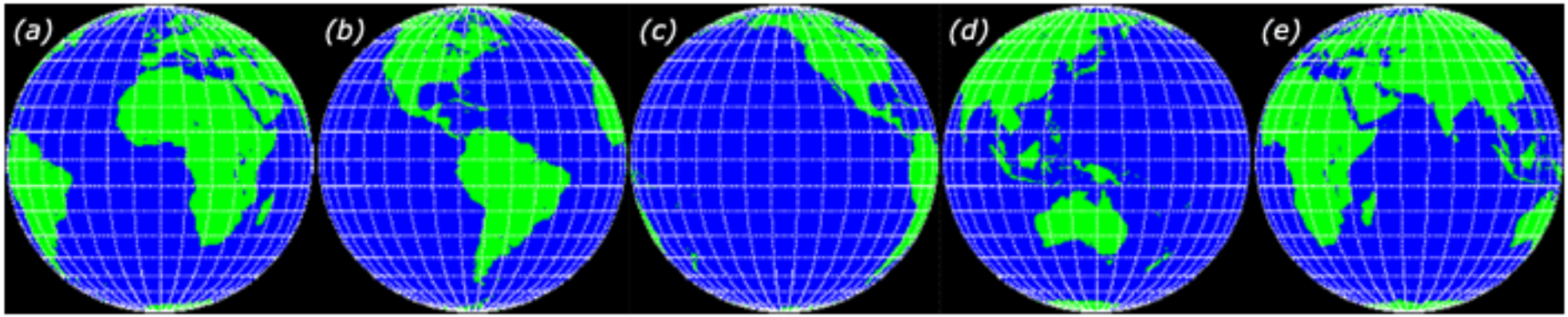


Mean yearly sums, 1995-2005
Source: University of Oldenburg

Irradiance from satellite data

- satellite data
- Heliosat method to derive irradiance

Coverage by geostationary satellites



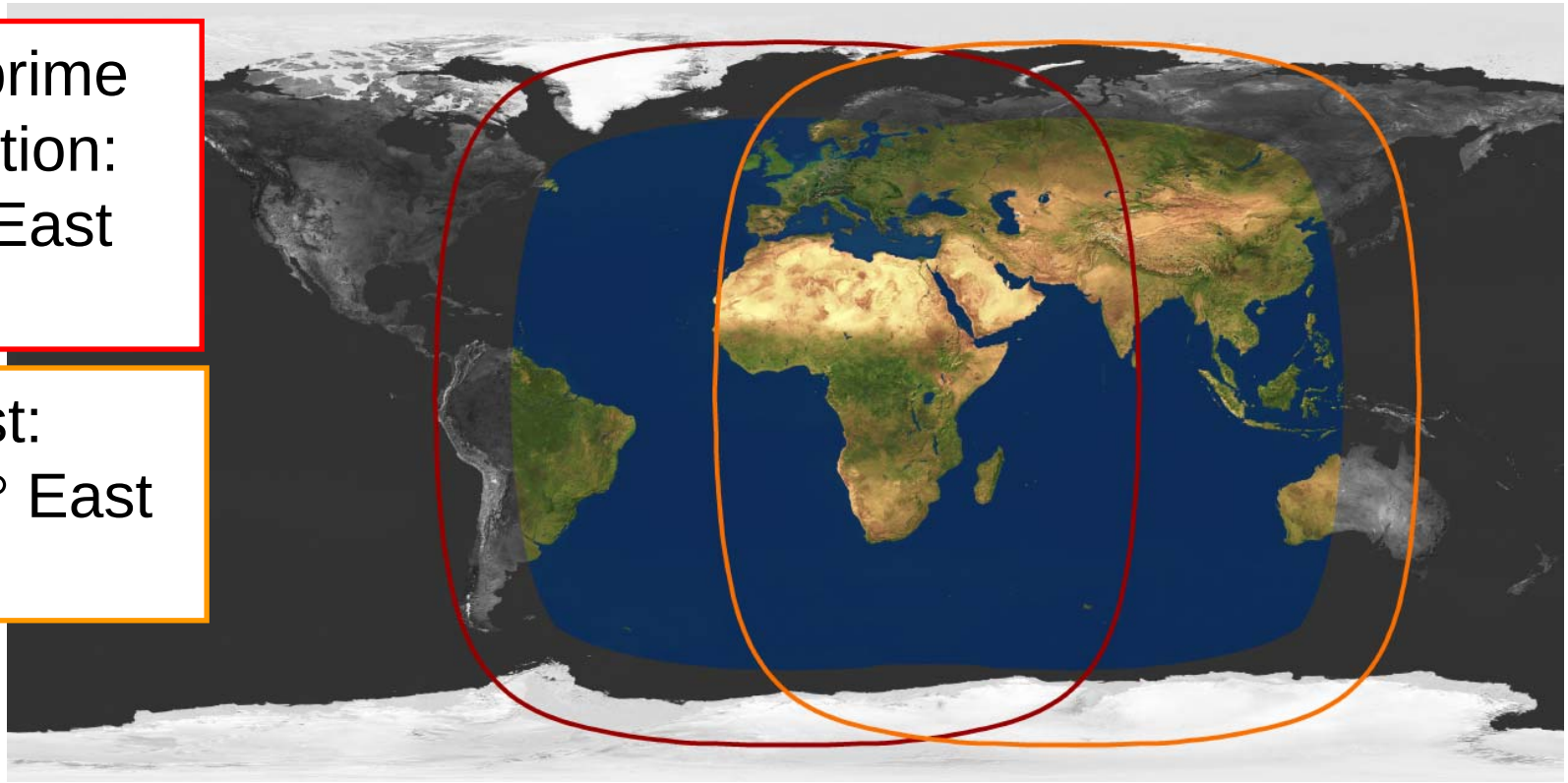
METEOSAT GOES-EAST GOES-WEST GMS IODC

coverage area map of geostationary satellites in operation
(source: http//swera.unep.net)

Coverage by Meteosat satellites

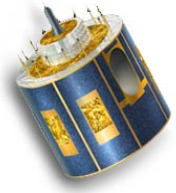
Meteosat at prime meridian position:
0° North / 0° East
from 1985 on

Meteosat east:
0° North / 63° East
from 1998 on



world map with the areas covered by Meteosat satellites (source: DLR)

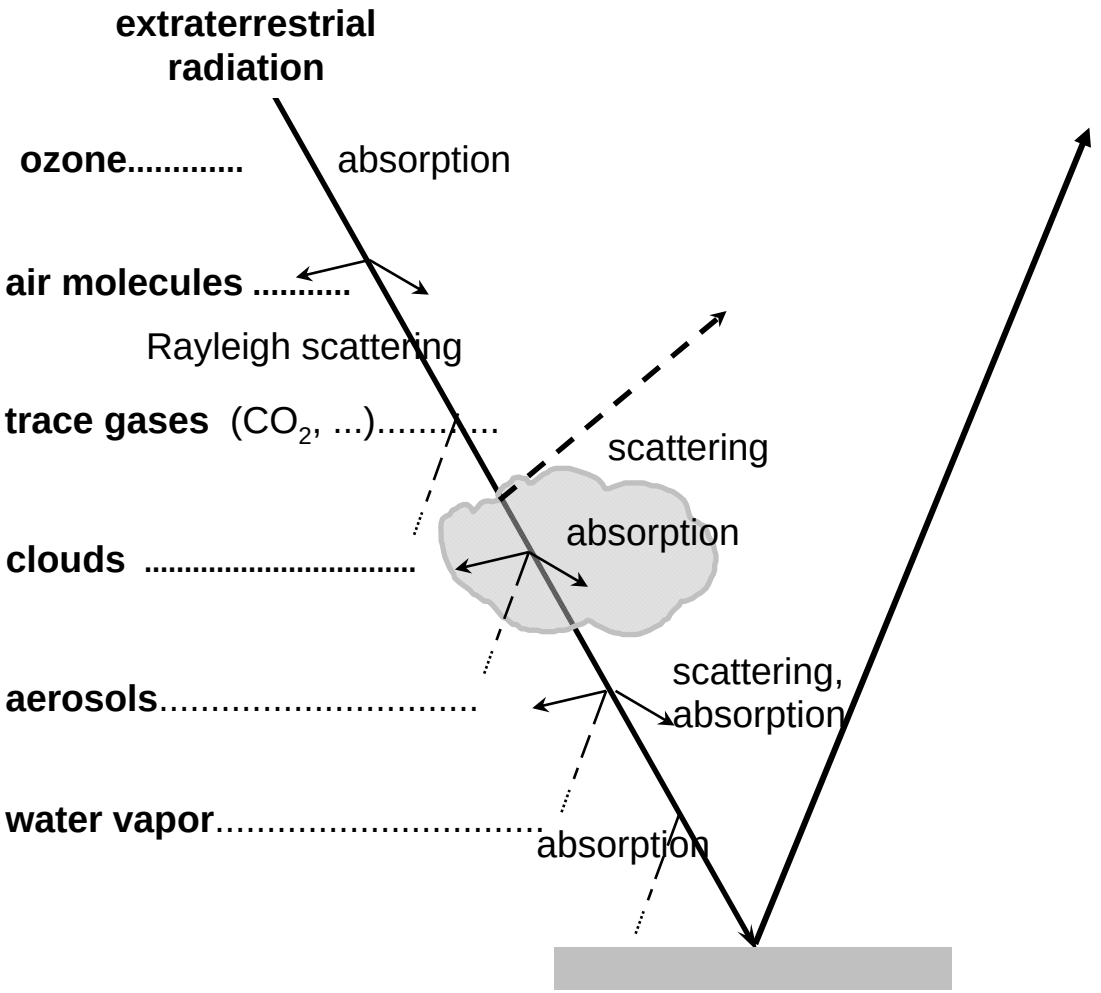
Meteosat first and second generation



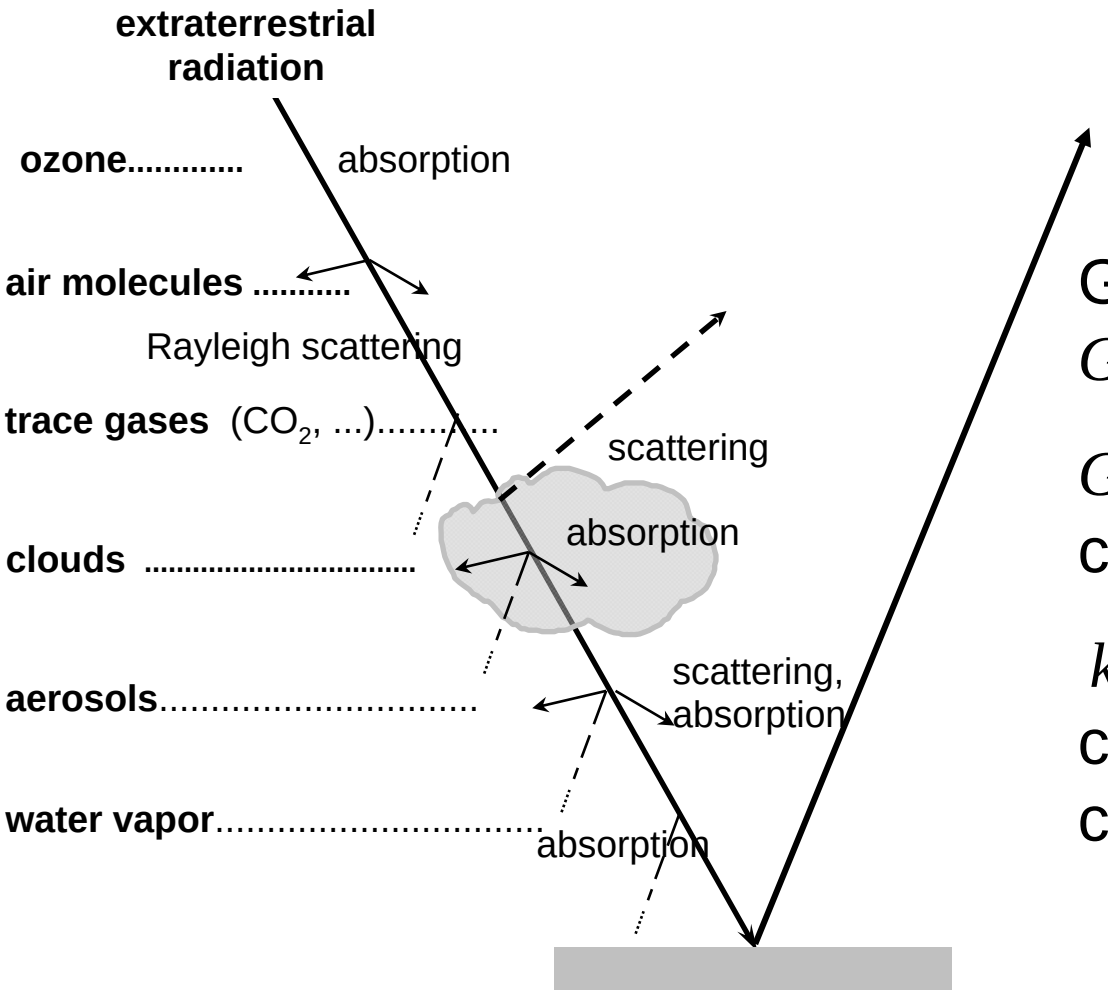
	MFG	MSG
period	1985-2005	2004 ongoing
spatial resolution*	2.5 km x 2.5 km	hr:1 km x 1 km lr: 3 km x 3 km
temporal resolution	30 min	15 min
spectral resolution	vis: 500-900 nm ir and wv broadband	hrv: 500-900 nm &11lr channels

*at sub- satellite point (0°/0°)

Atmospheric extinction processes



Atmospheric extinction processes



Global irradiance

$GHI = k^* \, GHI_{clear}$

GHI_{clear}:
clear sky global irradiance

k^*:
clear sky index, describes cloud transmissivity

Clear sky

Definition: cloudless sky

maximum possible insolation at a given site, time and atmospheric conditions

used as normalization function for most of radiation models

clean

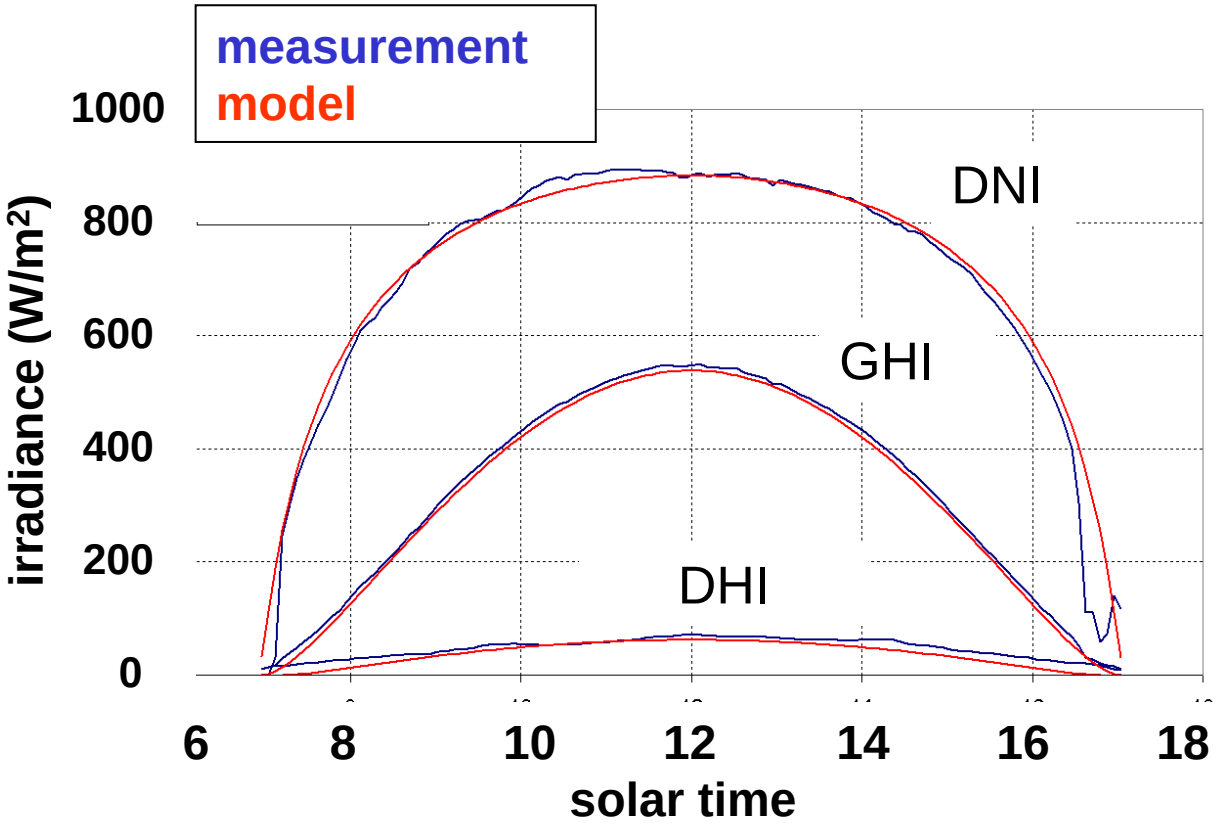
turbid

I_{clear} = f(geometry, air molecules, ozone,aerosols, water vapour)

Clear sky

Atmospheric transmission:

- geometry
- constant effect: NO_2, CO_2, O_2, N, etc
- slight dependence: O_3
- strong dependence: water vapour, aerosols



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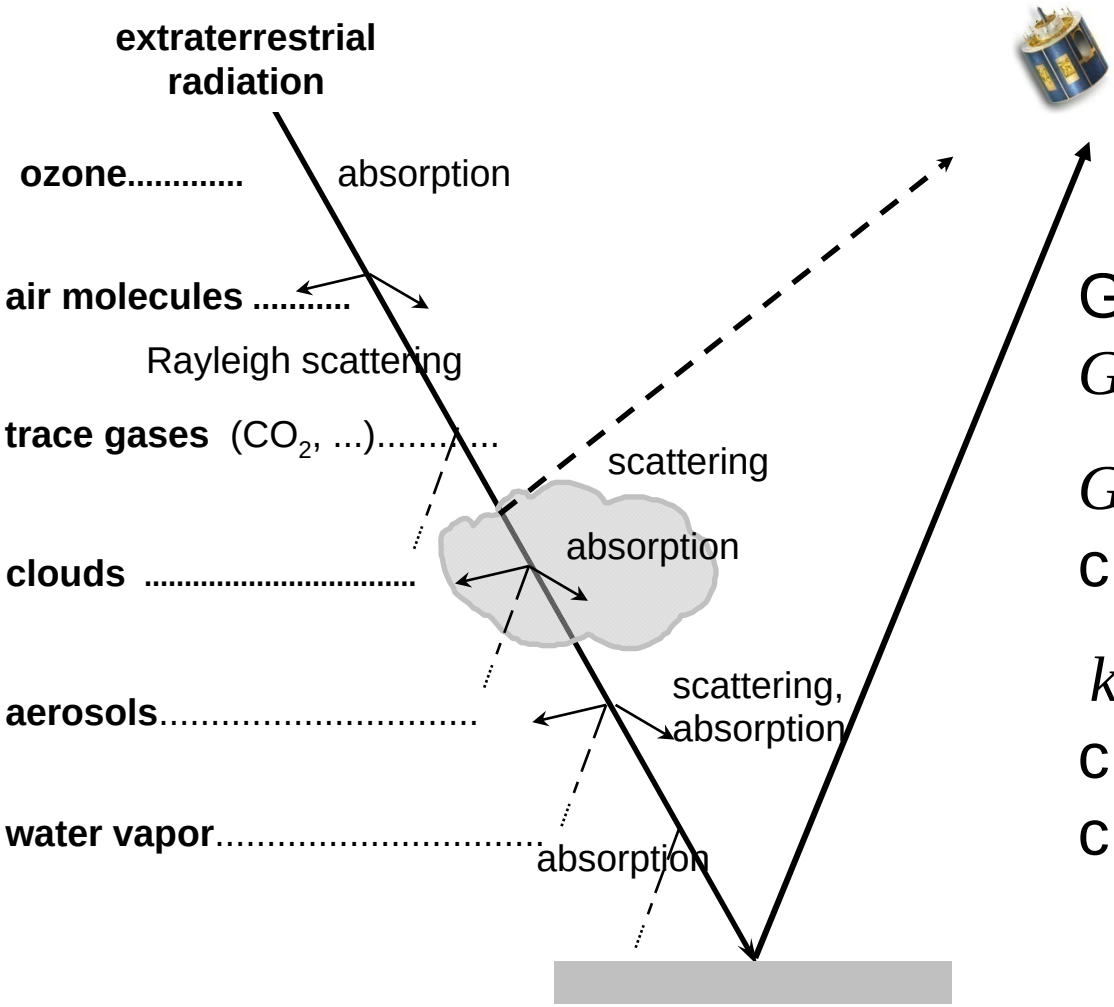


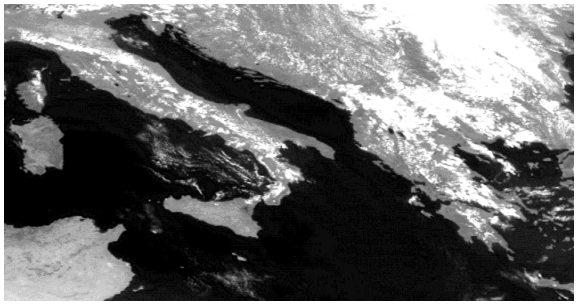
Global irradiance

$GHI = k^* \, GHI_{clear}$

GHI_{clear}:
clear sky global irradiance

k^*:
clear sky index, describes cloud transmissivity

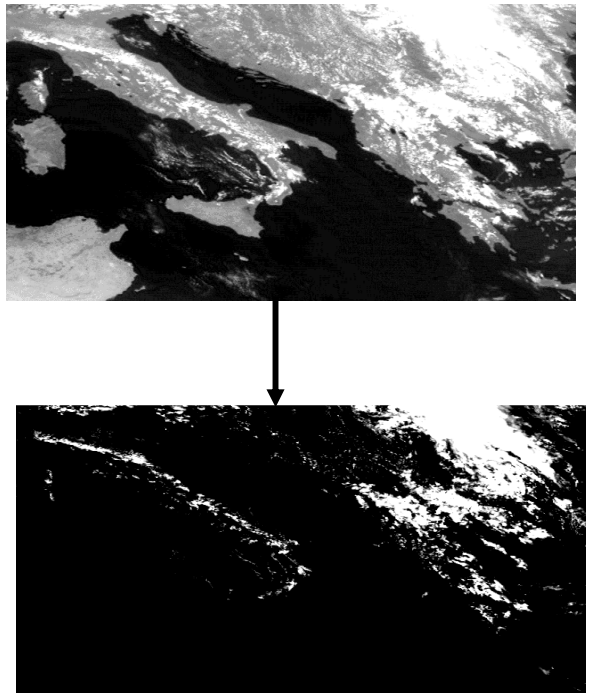
Heliosat method



satellite images:

- bright clouds
- dark surface

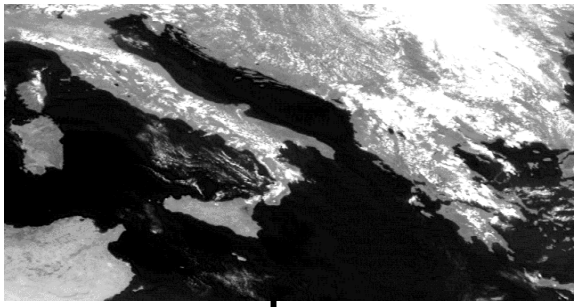
Heliosat method



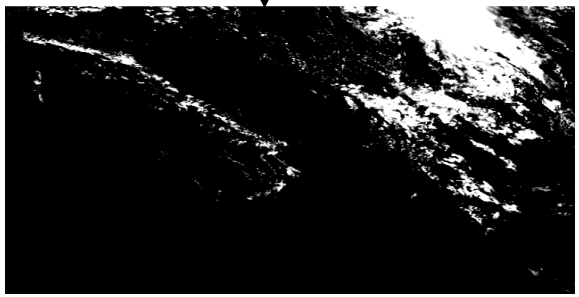
satellite images:
- bright clouds
- dark surface

cloud index images:
measure of cloudiness

Heliosat method

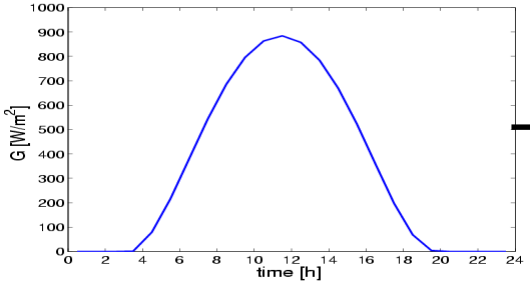


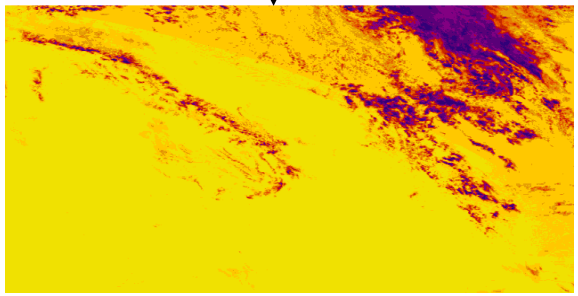
satellite images:
- bright clouds
- dark surface



cloud index images:
measure of cloudiness

clear sky model



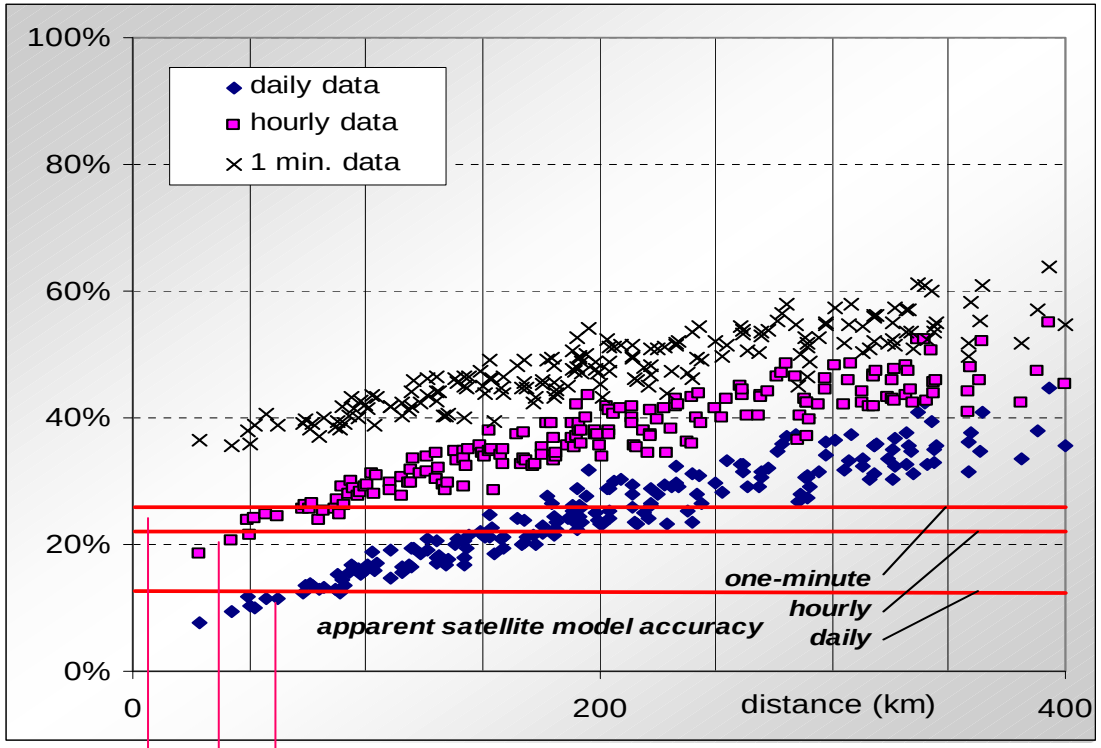


0 W/m²

500 W/m² global irradiance

1000 W/m²

Interpolated ground vs satellite data



source:
Perez, 2005

Daily breakeven distance	~ 60 km
Hourly breakeven distance	~ 35 km
1-minute breakeven distance	~ < 5 km

Overview

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Overview

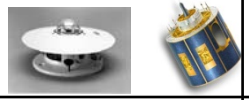
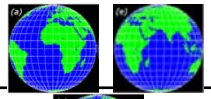
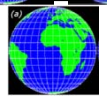
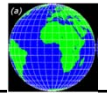
- sources of irradiance information
  - ground measurements
  - satellite data
  - reanalysis of numerical weather prediction models and climate models
    -> usually not applied for solar resource assessment
- overview on resource products

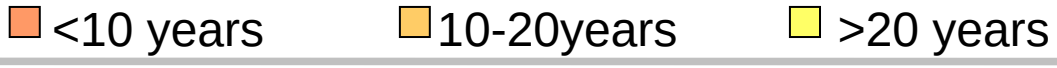
Resource products: input and extension

product	input	area	period	provider
NASA SSE	ISCCP	World	1983-2005	NASA
Meteonorm	*	World	1981-2000	Meteotest
Solemi			1991->	DLR
Helioclim			1985->	Mines-ParisTech
EnMetSol			1995->	Univ. of Oldenburg
Satel-light		Europe	1996-2001	ENTPE
PVGIS Europe	*	Europe	1981-1990	JRC
ESRA	*	Europe	1981-1990	Mines-ParisTech

*world radiation data center

Resource products: input and extension

product	input	area	period	provider
NASA SSE		World	1983-2005	NASA
Meteonorm		World	1981-2000	Meteotest
Solemi			1991->	DLR
Helioclim			1985->	Mines-ParisTech
EnMetSol			1995->	Univ. of Oldenburg
Satel-light		Europe	1996-2001	ENTPE
PVGIS Europe		Europe	1981-1990	JRC
ESRA		Europe	1981-1990	Mines-ParisTech



Resource products: resolution

product	input	temp resolution	spatial resolution
NASA SSE	ISCCP	averag. daily profile	100 km
Meteonorm		synthetic hourly/min	1 km (+SRTM)
Solemi		1h	1 km
Helioclim		15min/30min	30 km // 3-7 km
EnMetSol		15min/1h	3-7 km // 1-3 km
Satel-light		30min	5-7 km
PVGIS Europe		averag. daily profile	1 km (+ SRTM)
ESRA		averag. daily profile	10 km

□ synthetic high resolution values □ measured high resolution values

Resource products: parameters

product	parameters
NASA SSE	GHI, DNI, DHI, clouds
Meteonorm	GHI,DNI,DHI, shadowing, illuminance
Solemi	GHI, DNI
Helioclim	GHI, DNI
EnMetSol	GHI, DNI,DHI, spectra
Satel-light	GHI,DNI, DHI, illuminance
PVGIS Europe	GHI,DHI, shadowing
ESRA	GHI, DNI, DHI

Resource products: access and price

product	access	price
NASA SSE	eosweb.larc.nasa.gov/sse	free
Meteonorm	CD or www.meteonorm.ch	410 €
Solemi	on request	on request
Helioclim	www.soda-is.it	on request
EnMetSol	on request	on request
Satel-light	www.satel-light.com	free
PVGIS Europe	www.pvgis	free
ESRA	CD	380€

internet CD on request

Resource products: access and price

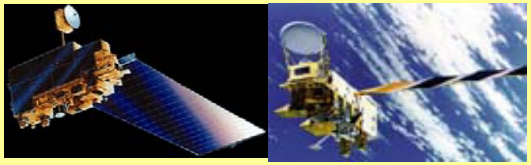
product	access	price
NASA SSE	eosweb.larc.nasa.gov/sse	free
Meteonorm	CD or www.meteonorm.ch	410 €
Solemi	on request	on request
Helioclim	www.soda-is.it	on request
EnMetSol	on request	on request
Satel-light	www.satel-light.com	free
PVGIS Europe	www.pvgis	free
ESRA	CD	380€

free low cost on request

NASA-SSE

Earth System Science → Applied Science Outcome

NASA Satellite Measurements, Analysis and Modeling



Terra Aqua

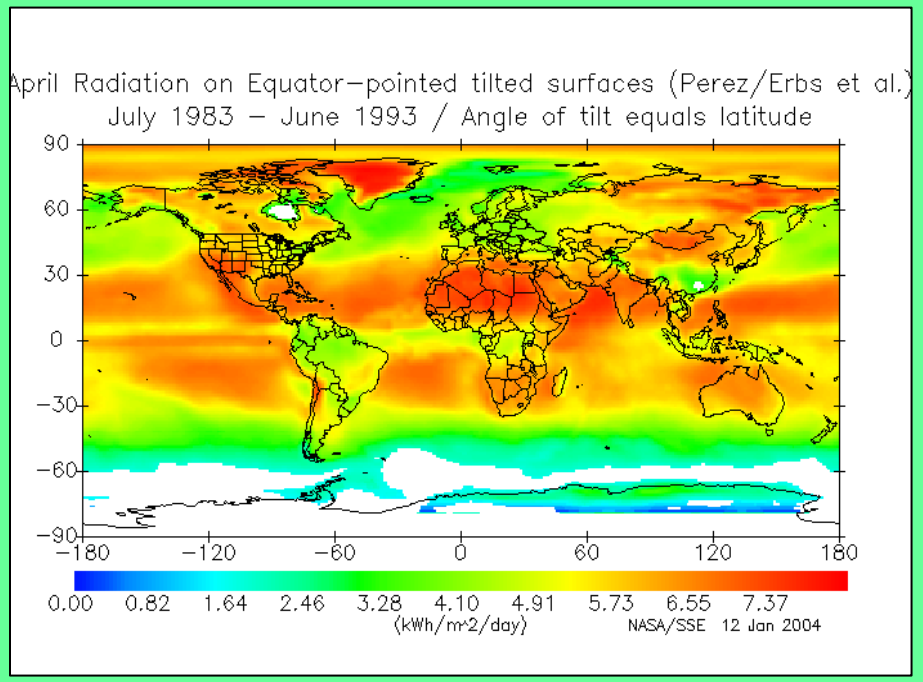
ISCCP SRB GMAO CERES

SSE Web Site

http://eosweb.larc.nasa.gov/sse/

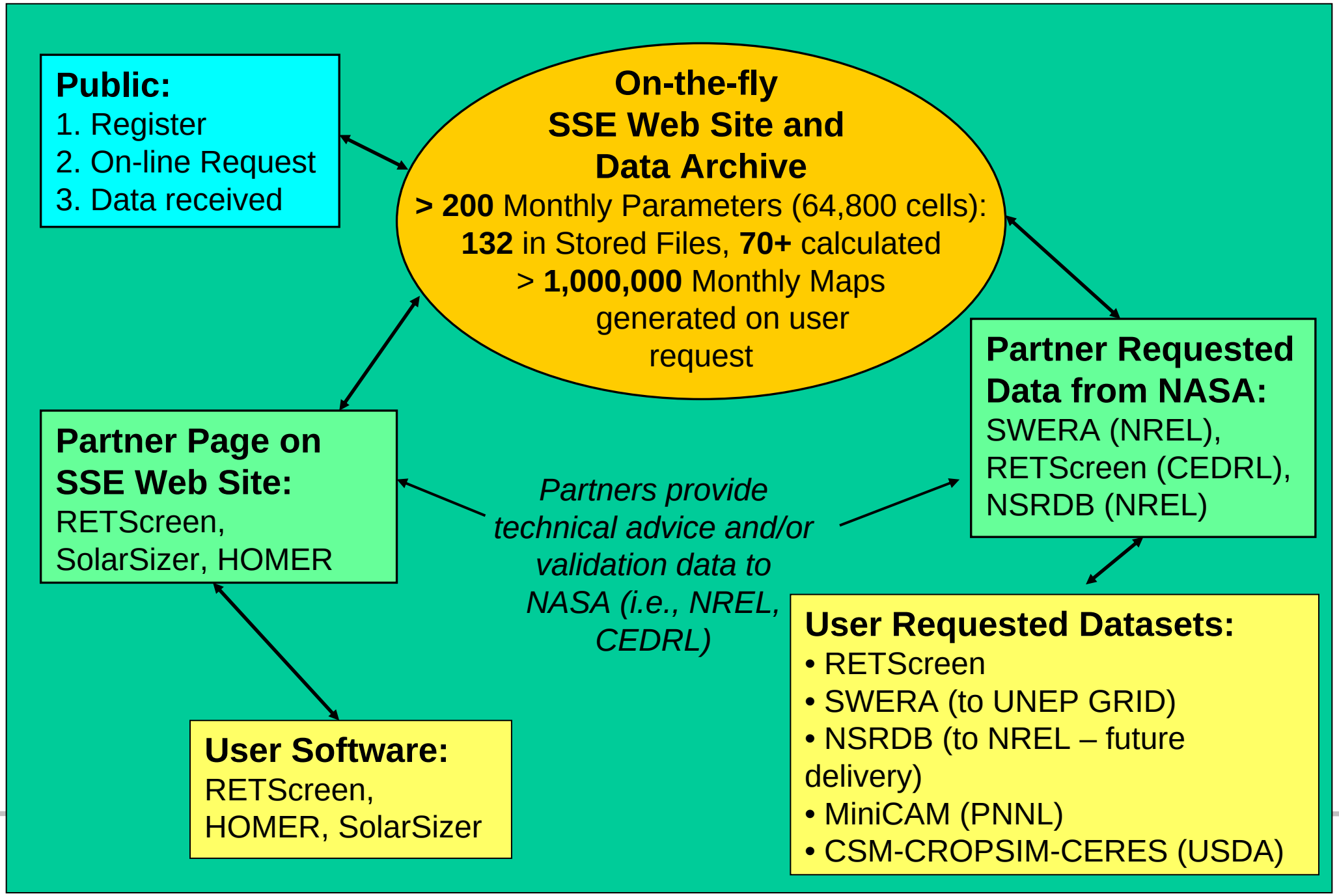
Over 200 solar energy and meteorology parameters averaged from 10 years of data

Surface Meteorology and Solar Energy (SSE) Datasets And Web interface



Growing over the last 7 years to nearly 14,000 users, nearly 6.4 million hits and 1.25 million data downloads

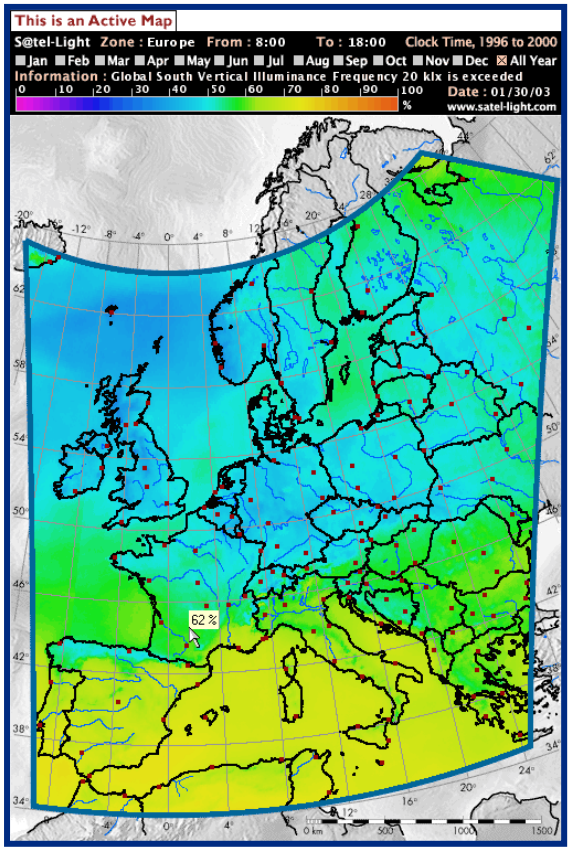
NASA-SSE


Public:
1. Register
2. On-line Request
3. Data received
On-the-fly
SSE Web Site and
Data Archive
> 200 Monthly Parameters (64,800 cells):
132 in Stored Files, 70+ calculated
> 1,000,000 Monthly Maps
generated on user
request
Partner Requested
Data from NASA:
SWERA (NREL),
RETScreen (CEDRL),
NSRDB (NREL)
Partner Page on
SSE Web Site:
RETScreen,
SolarSizer, HOMER
Partners provide
technical advice and/or
validation data to
NASA (i.e., NREL,
CEDRL)
User Requested Datasets:
• RETScreen
• SWERA (to UNEP GRID)
• NSRDB (to NREL – future
delivery)
• MiniCAM (PNNL)
• CSM-CROPSIM-CERES (USDA)
User Software:
RETScreen,
HOMER, SolarSizer

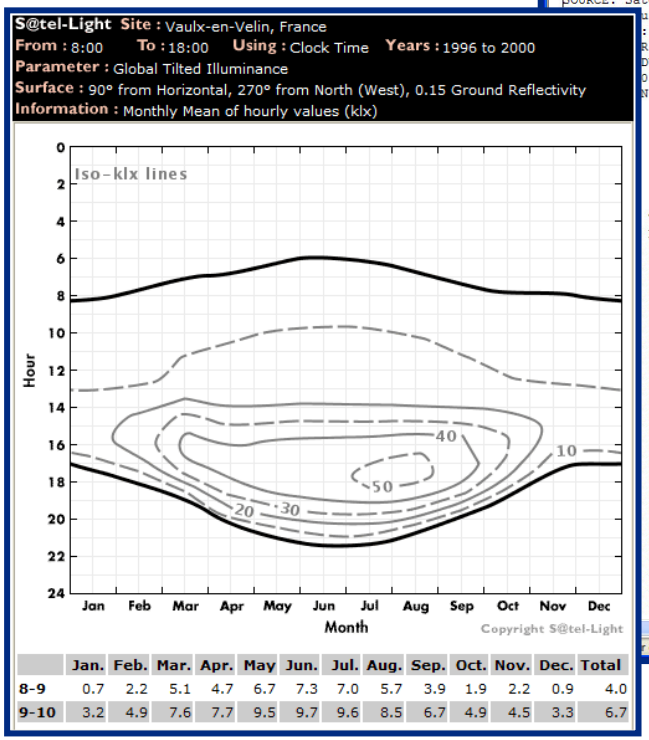
A short glimpse at what you get !

5 years of half hour data from 1996 to 2000

Maps

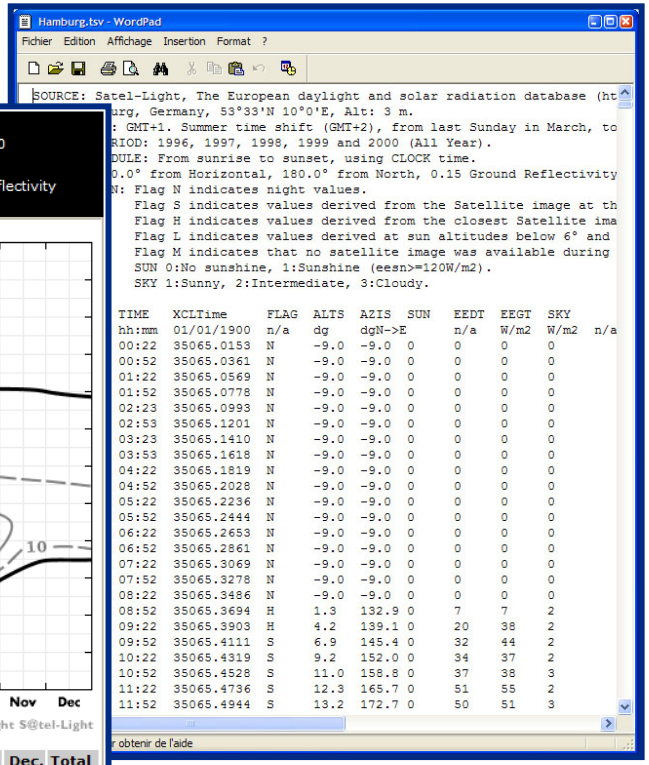


Diagrams



	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
8-9	0.7	2.2	5.1	4.7	6.7	7.3	7.0	5.7	3.9	1.9	2.2	0.9	4.0
9-10	3.2	4.9	7.6	7.7	9.5	9.7	9.6	8.5	6.7	4.9	4.5	3.3	6.7

Data files



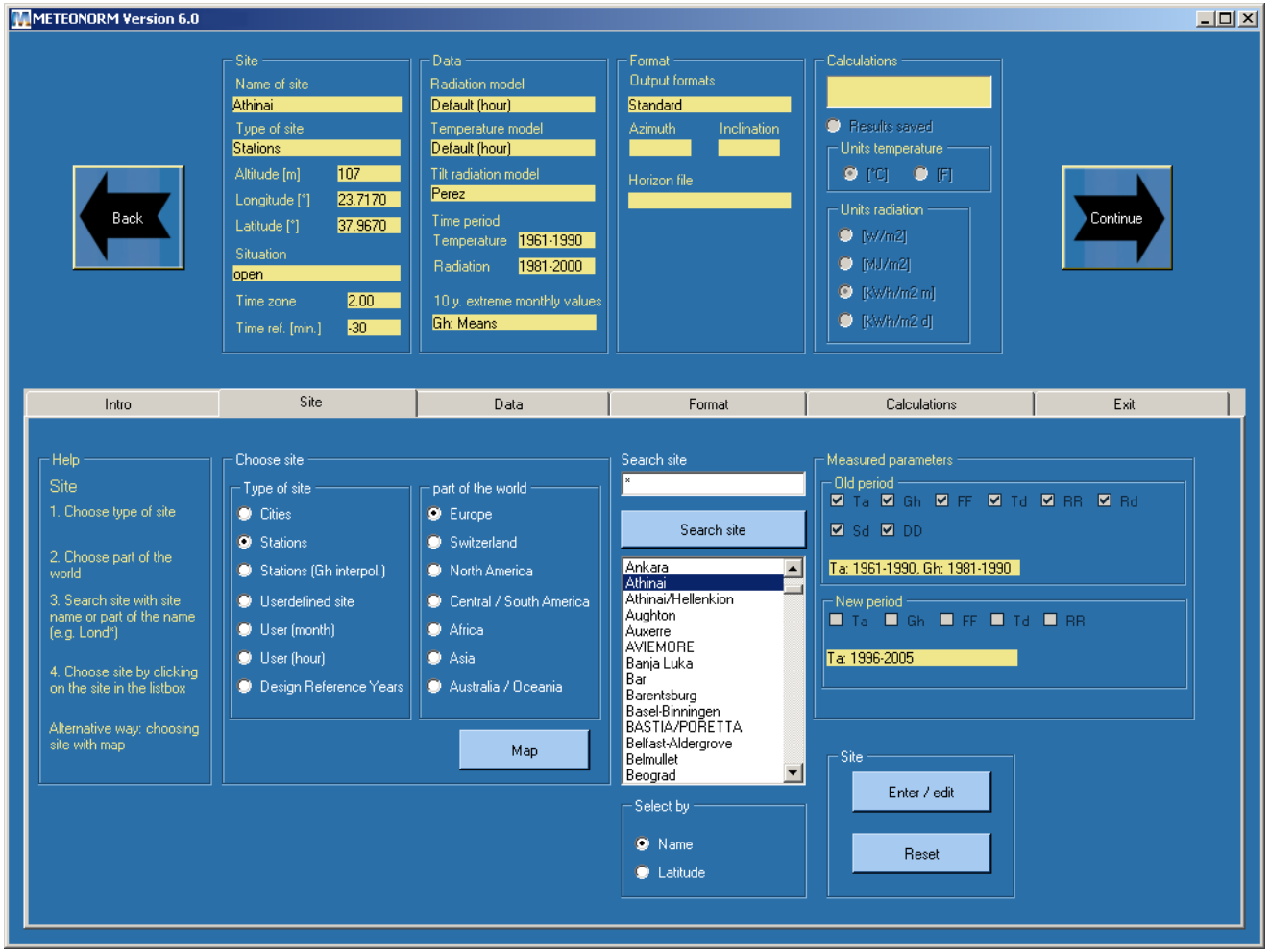
What parameters are available ?

- global irradiance
- diffuse horizontal irradiance from global
  (Olseth & Skartveit diffuse fraction model)
- tilted irradiances with Perez model
- temperatures with Dumortier model
  (from min/max daily and global irradiance)
- illuminances with Olseth luminous efficacy model
- sky luminances with the Perez ASRC-CIE model

Basic data / software

4 steps:

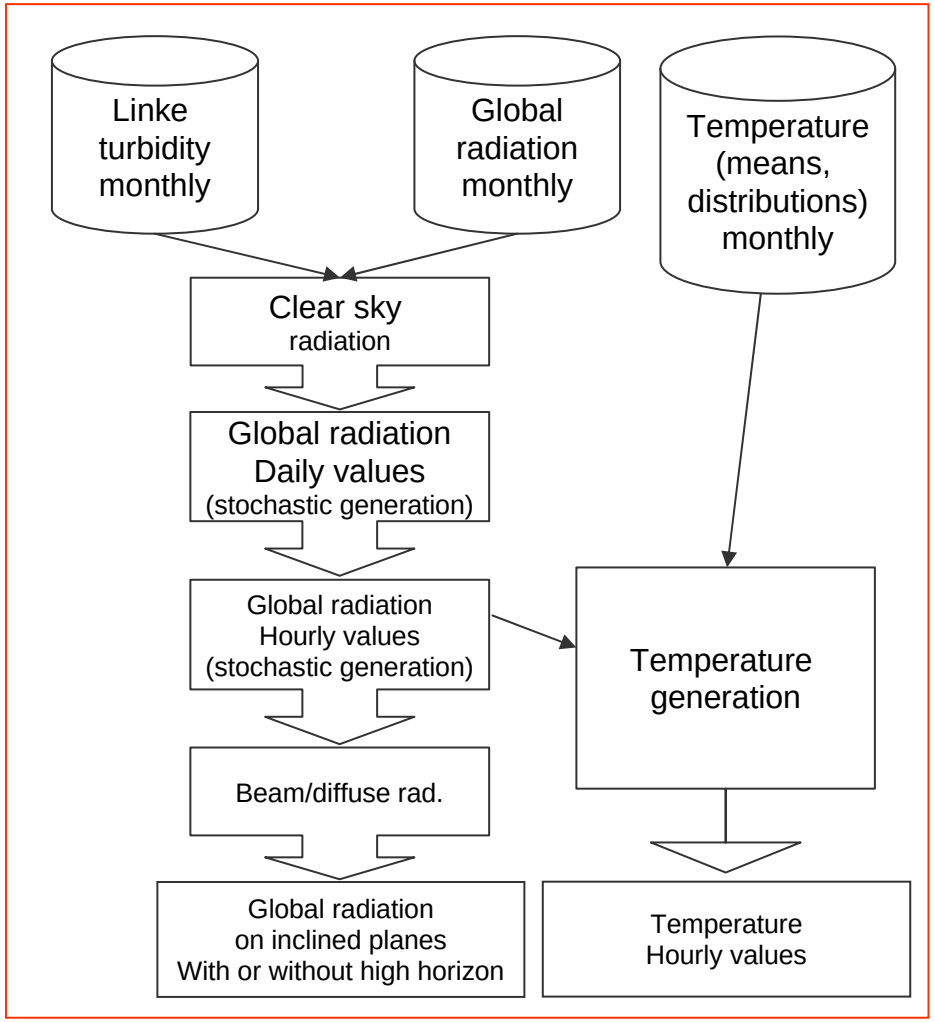
- site
- data
- format
- calculations



Climate data

- 8050 stations
- 8 parameters:
  - global radiation (horizontal, inclined)
  - air temperature
  - dewpoint temperature
  - wind speed and direction
  - sunshine duration
  - precipitation
  - days with precipitation

Chain of algorithms



PVGIS provides free access to…

data

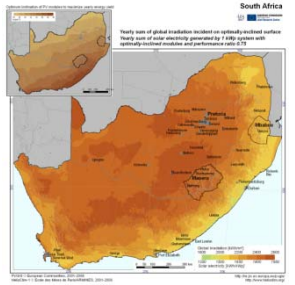
- solar radiation (Europe, Africa & SW Asia
- ambient temperature (Europe)
- + terrain, land cover…

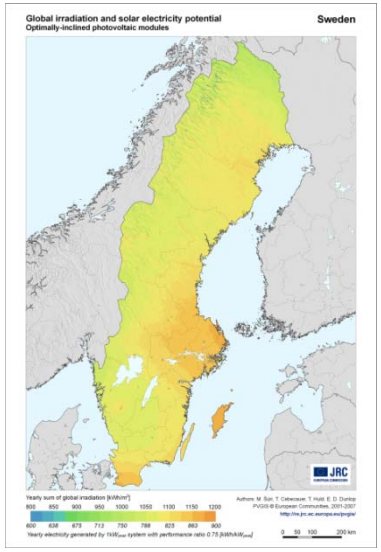
assessment tools

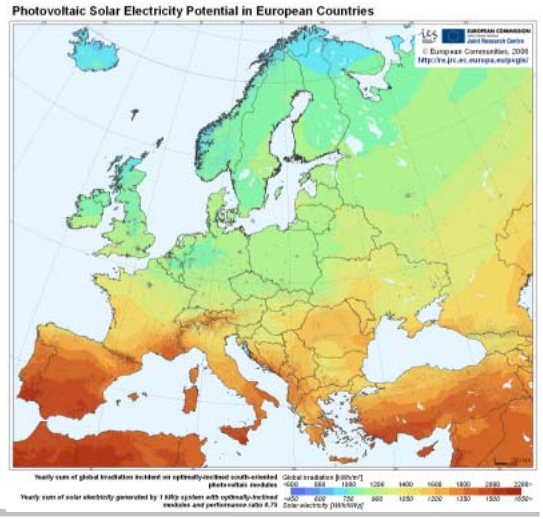
- solar radiation for fixed and sun-tracking surfaces
- output from grid-connected PV
- performance of standalone PV (only Africa)

maps

- interactive
- static







Calculation of grid-connected PV performance

calculation takes into account angle-of-incidence effects

- For crystalline silicon and CIS/CIGS, the effects of temperature and irradiance on the conversion efficiency are modeled.
- generic (user-selected) value for BOS losses
- calculates output for:
  - specified inclination and orientation
  - optimum inclination for given orientation
  - optimum inclination and orientation
  - 1- and 2-axis flat-plate tracking

Common Features

- same area for H1, H2, H3
- uncertainties of irradiance values assessed and provided
- dissemination through the SoDa Service *www.soda-is.com*
- access to data in one click
- access on-pay, except 1985-1989 (daily) and 2005
- coupled to other services, e.g. irradiance on inclined surface

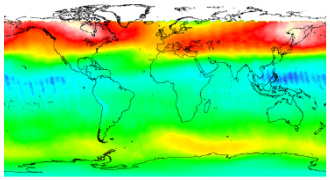
Differences

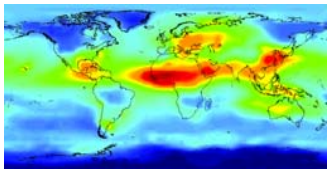
HC1	Daily	-	5 km – 30 km	1985 - 2005	Heliosat 2
HC2	1 h	TST	5' fixed (10 km)	Real Time 2004 ➔	Heliosat 2
HC3	¼ h	UT, TST	pixel 3 km	Real Time 2004 ➔	Heliosat 2

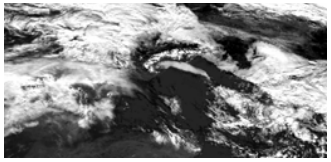
HC-3 is more accurate than HC-2

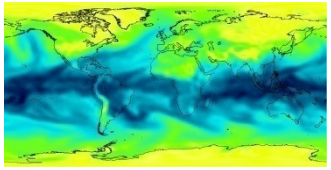
Some of the highlights

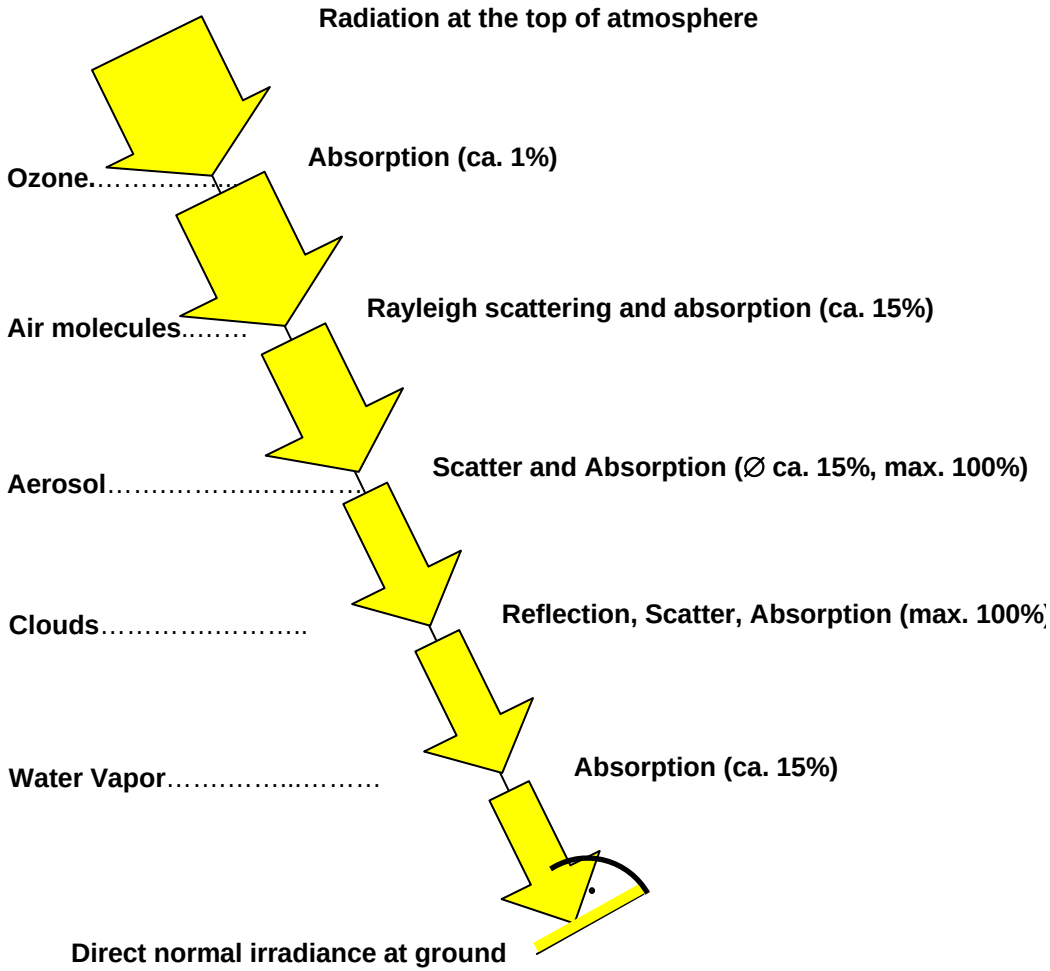
- Large spatial extension
- > 15 years
- full satellite resolution
- seperate teatment of atmospheric componets





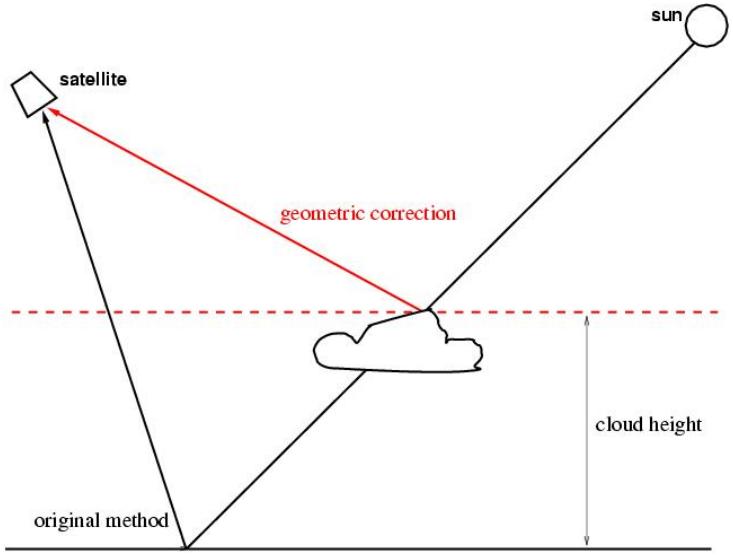


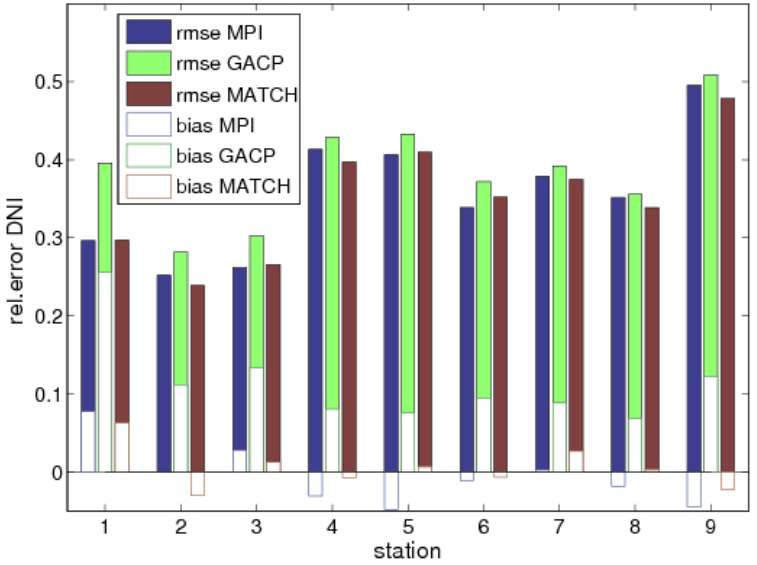




Main features

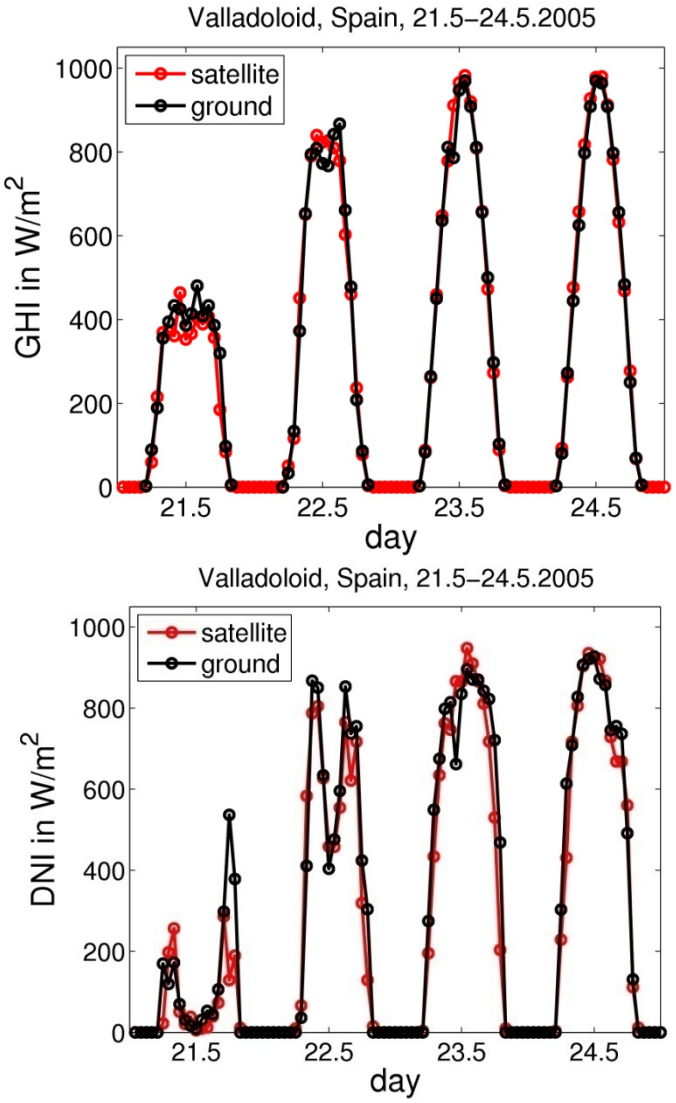
- 13 years
- full satellite resolution
- **continuous model development**
  - parallax correction using cloud hight
  - broken clouds correction
  - snow detection
  - investigation of appropriate atmospheric data sets





Main features

- 13 years
- full satellite resolution
- **continuous model development**
  - parallax correction using cloud hight
  - broken clouds correction
  - snow detection
  - investigation of appropriate atmospheric data sets
- **validation studies for requested sites/regions**



Summary

different sources of irradiance information

- ground data
- satellite data

resources products

- different input data and methods
- different spatial and temporal resolutions
- different coverage
- different accuracy