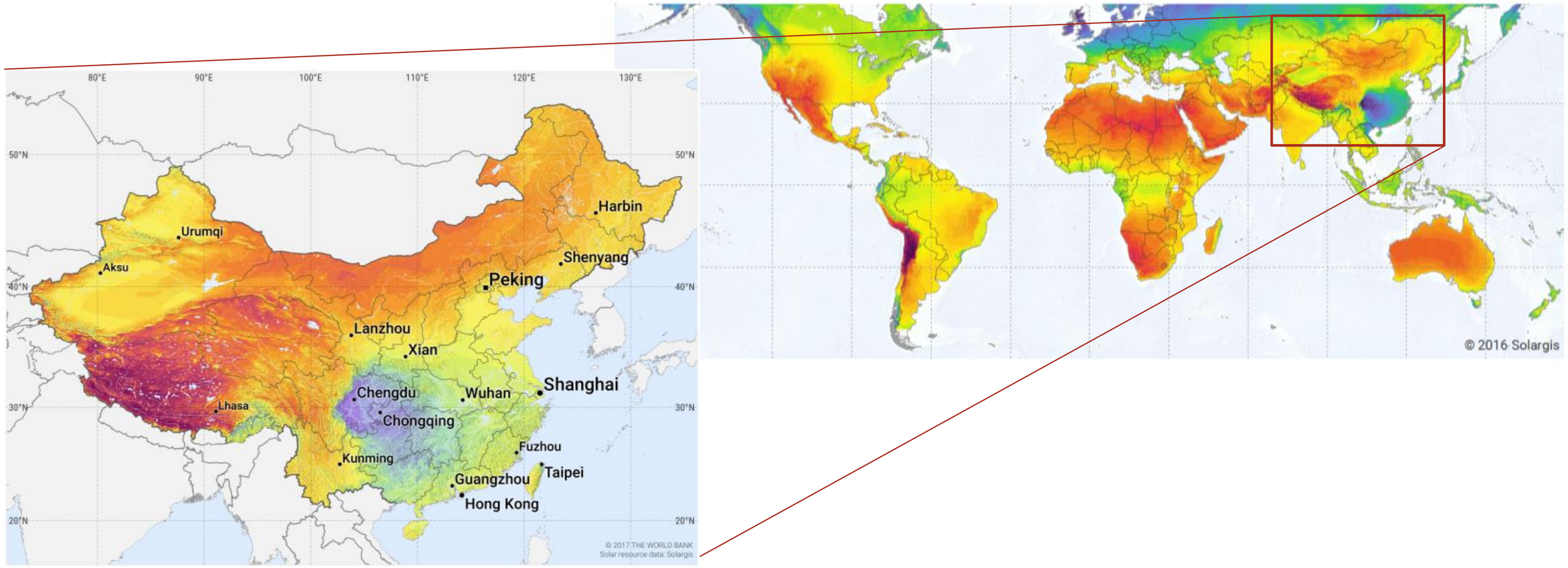

Solargis weather database for China

Status of development

Marcel Suri, Tomas Cebecauer, Jose A. Ruiz-Arias, and Artur Skoczek

Solargis, Slovakia

solargis.com

9th PV Performance Modeling and Monitoring Workshop. Weihai, China, 5-6 December 2017

SOLARGIS

About Solargis

Solar resource, weather and photovoltaic simulation data, software and expert services

- Prospection
- Project development
- Monitoring
- Forecasting

Distributors in China:

SOLARMETEO powered by Solargis

RETEC 瑞科科技

600+ customers in 90+ countries

17 year experience in solar energy

Content

- Data needed for PV simulations
- Old and modern data approaches
- Solar and weather data acquisition
  - Meteorological measurements
  - Satellite-based solar models
  - Meteorological models
- Validation of solar radiation data
- Validation of meteorological data
- PV power forecasting
- Integrated data flow for continuous PV simulations

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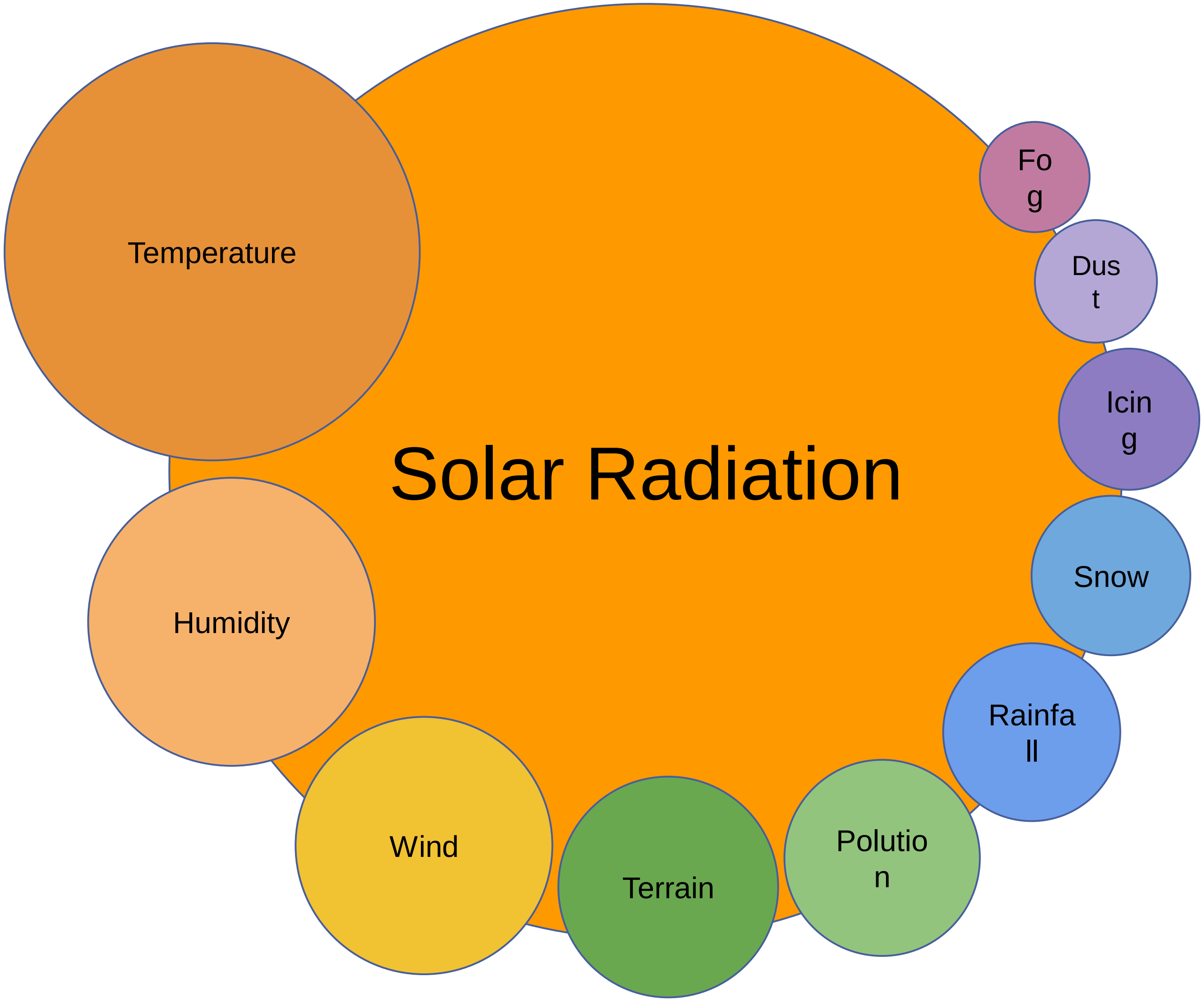
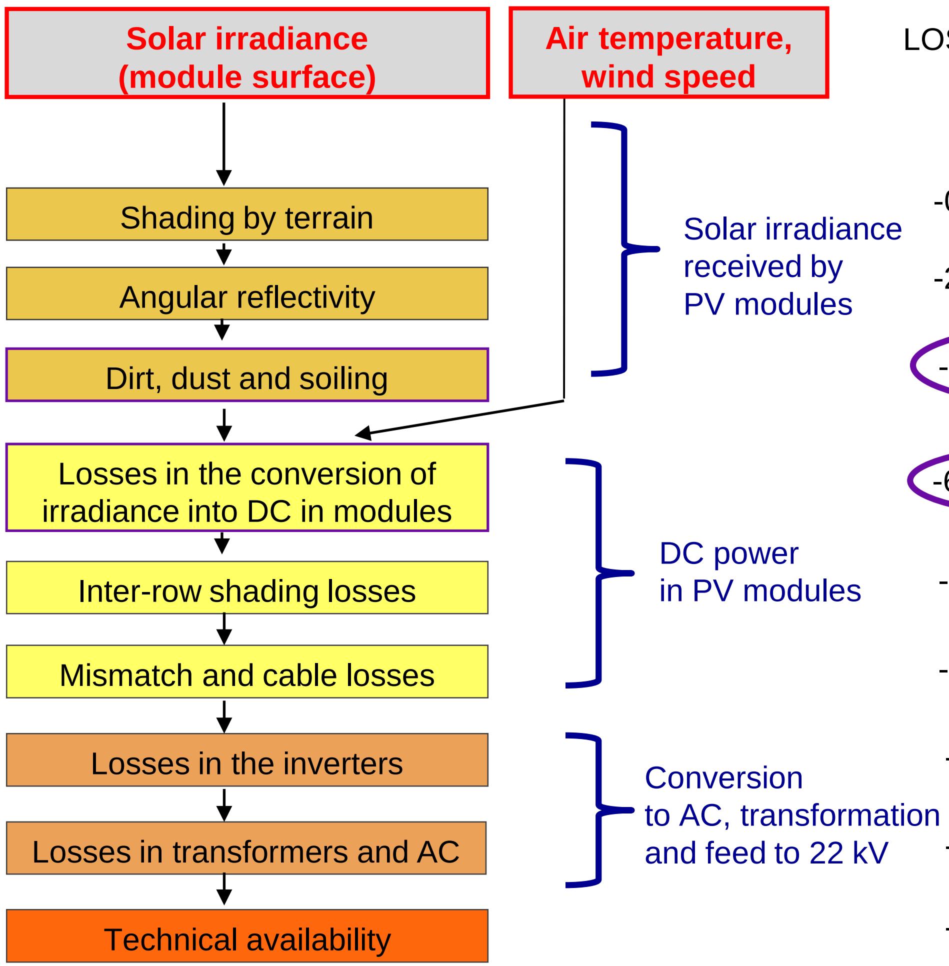
PV production depends on environment



PV simulation chain

example Weihai, China

PV performance in Standard Test Conditions: 1659 kWh/kWp

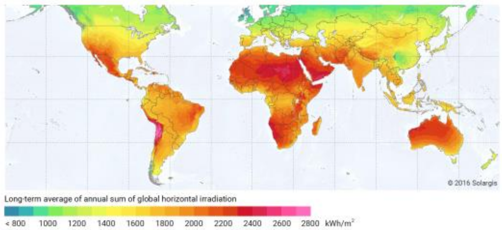


	LOSSES	UNCERTAINTY
Solar irradiance (module surface)		±6.5%
Shading by terrain	-0.5%	±0.1%
Angular reflectivity	-2.9%	±0.5%
Dirt, dust and soiling	-3.0%	±2.0%
Losses in the conversion of irradiance into DC in modules	-6.4%	±3.0%
Inter-row shading losses	-0.5%	±0.2%
Mismatch and cable losses	-2.0%	±0.8%
Losses in the inverters	-2.5%	±1.0%
Losses in transformers and AC	-1.5%	±0.5%
Technical availability	-1.0%	±1.0%

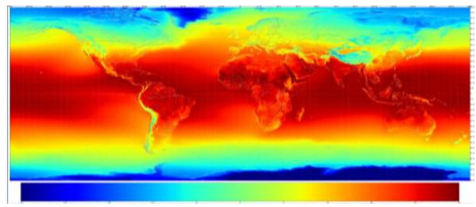
PV annual output: 1347 kWh/kWp, losses 11.2% (PR=81.2%), uncertainty: 7.6%

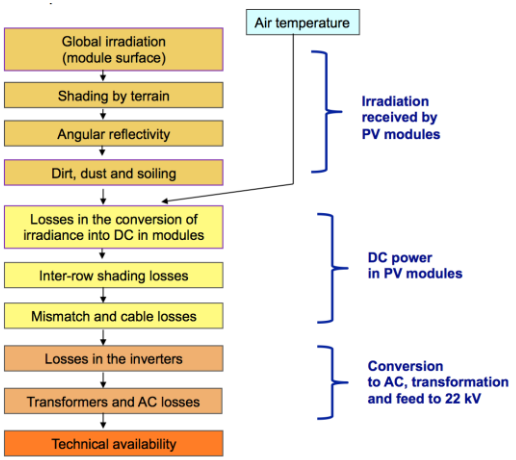
World PV power potential

Solar radiation

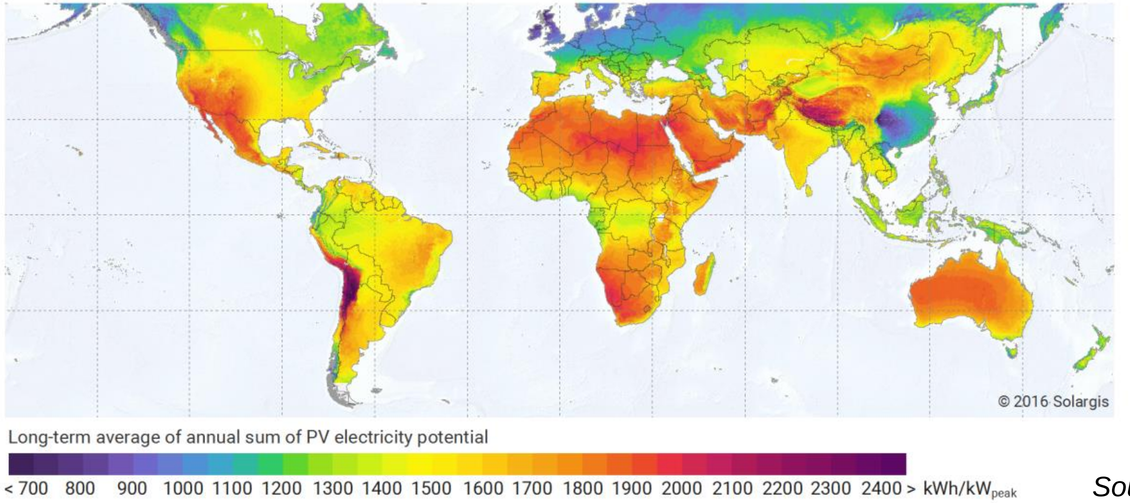


Air temperature





PV power potential



Source: Solargis

Assumptions:

- Inputs: global irradiance at inclined plane and air temperature
- PV technology setup: cSi modules, fixed mounting at optimum angle, high eff. inverter, 100% availability

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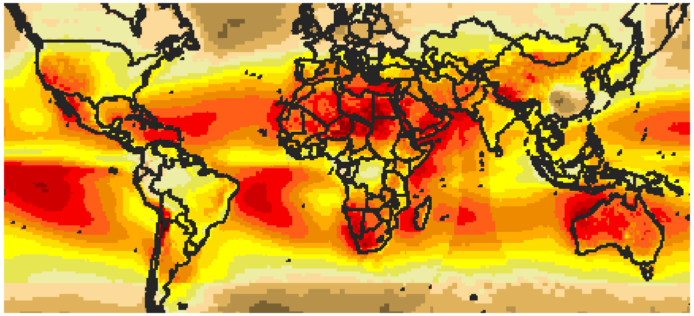
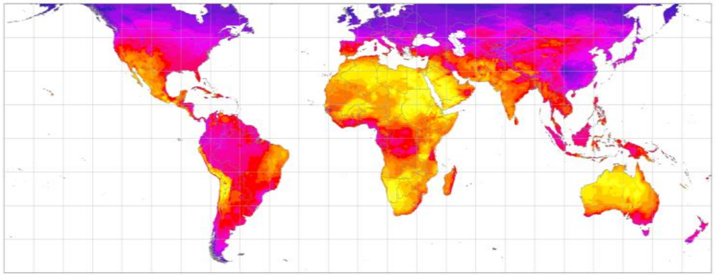
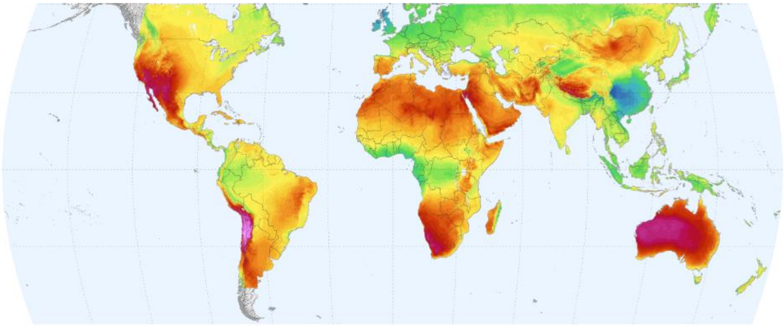
Data available for China

Data sources

- China Meteorological Agency
- NASA SSE
- Meteonorm
- Solargis
- ...







Source: NASA/SWERA, Meteonorm , Solargis

Solar resource

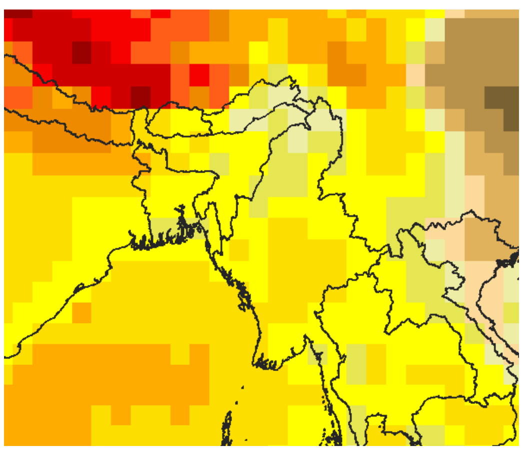
Comparing historical and modern approaches

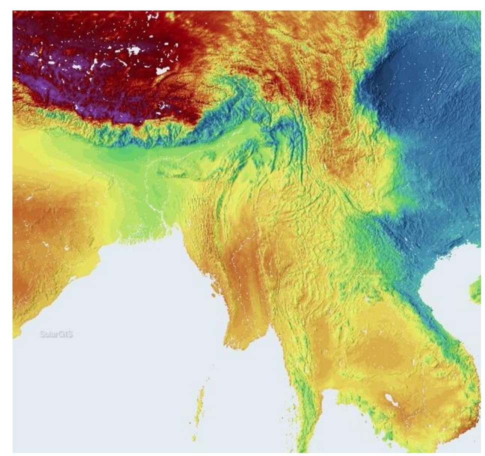
Historical approaches

- Simplified “old” models and inputs
- Static (no regular updates)
- Little validation
- Low resolution
- Heterogeneous quality
- No support

New approaches

- Systematic development and operation
- Modern semi-physical models and inputs
- Updated in real time
- Systematic validation
- High temporal and spatial resolution
- Global and harmonized
- Technical and commercial support





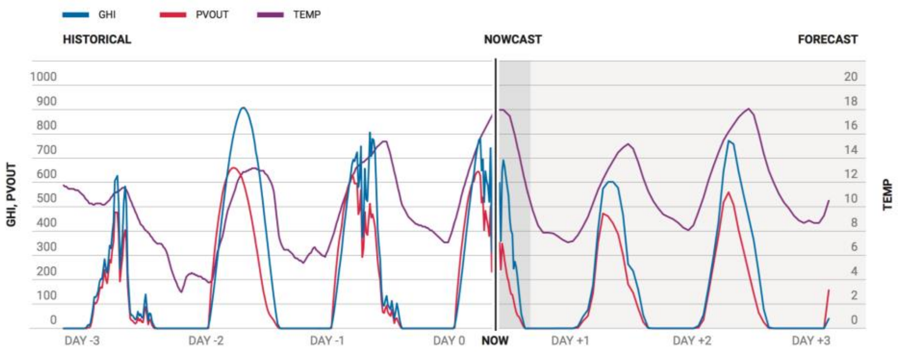
Requirements for solar resource data

Global

Long historical record

High accuracy (validated)

Detailed (temporal, spatial)



Continuity

- Historical data
- Real-time data for monitoring, nowcasting and forecasting

This is possible with a combination of several approaches

- Satellite-based models
- Meteorological models
- High-quality ground measurements

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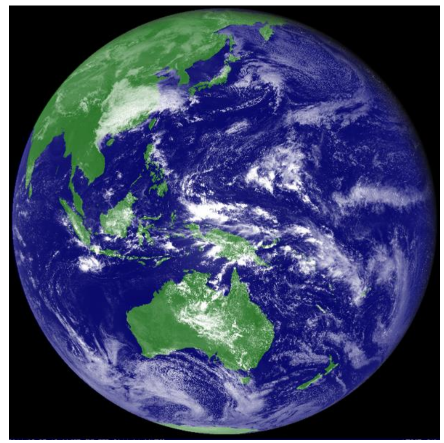
Acquiring solar and weather data

Ground measurements

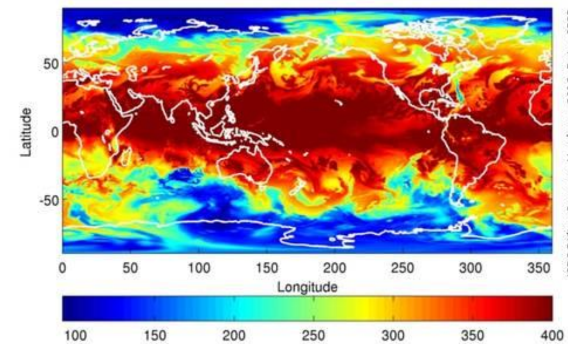
Source: CSP Services

Satellite models



Source: JMA

Meteorological models



Source: NOAA

	Ground measurements	Satellite models	Meteorological models	
			Reanalysis models	Numerical weather prediction models
Solar data	Calibration and validation od models	Historical solar data and nowcast	-	Forecast
Meteorological data	Detailed local analysis	-	Historical meteo data	

Acquiring solar and weather data

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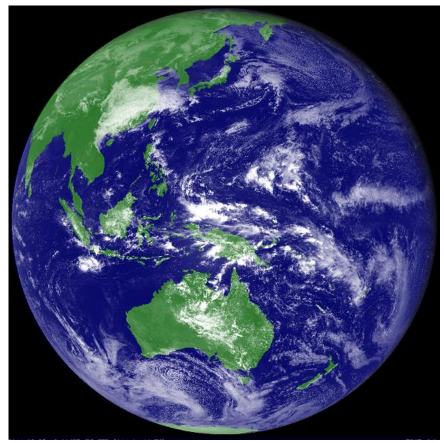
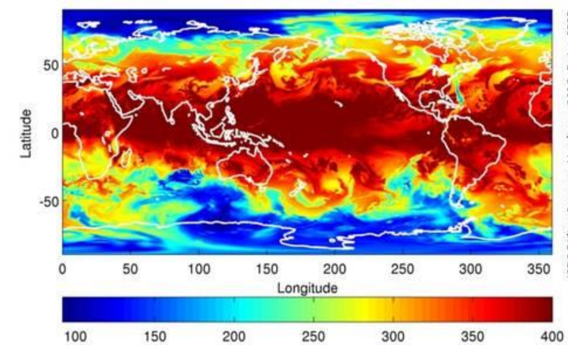
Source: CSP Services

Satellite models



Source: JMA

Meteorological models



Source: NOAA

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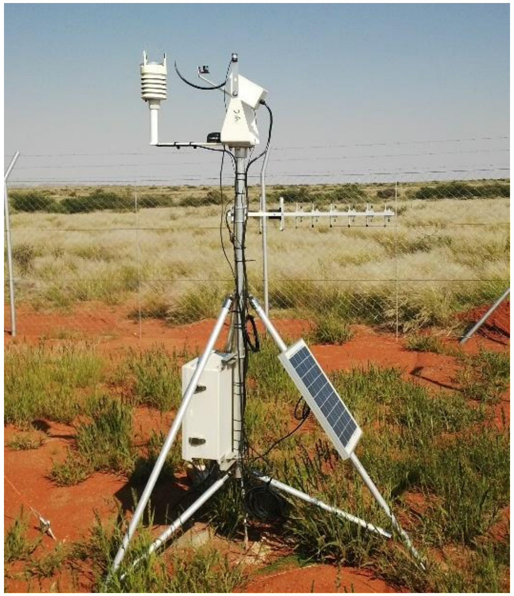
Ground measurements

- **Objective**: Acquiring detailed and accurate data for calibration and validation of models:
  - Solar parameters: direct, diffuse, global
  - Meteorological parameters: temperature, wind, humidity, rainfall, etc.
- **High-accuracy instruments** should be used:
  - Secondary-standard pyranometers
  - First class pyrheliometers
  - Rotating shadowband (for remote locations)
- **Regular cleaning, maintenance and calibration**
- More than one solar sensor to be installed (redundancy)
- Station to be managed by trained personnel



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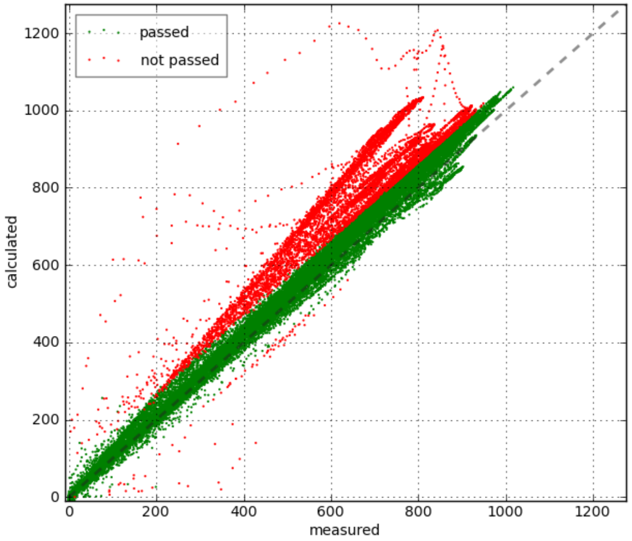
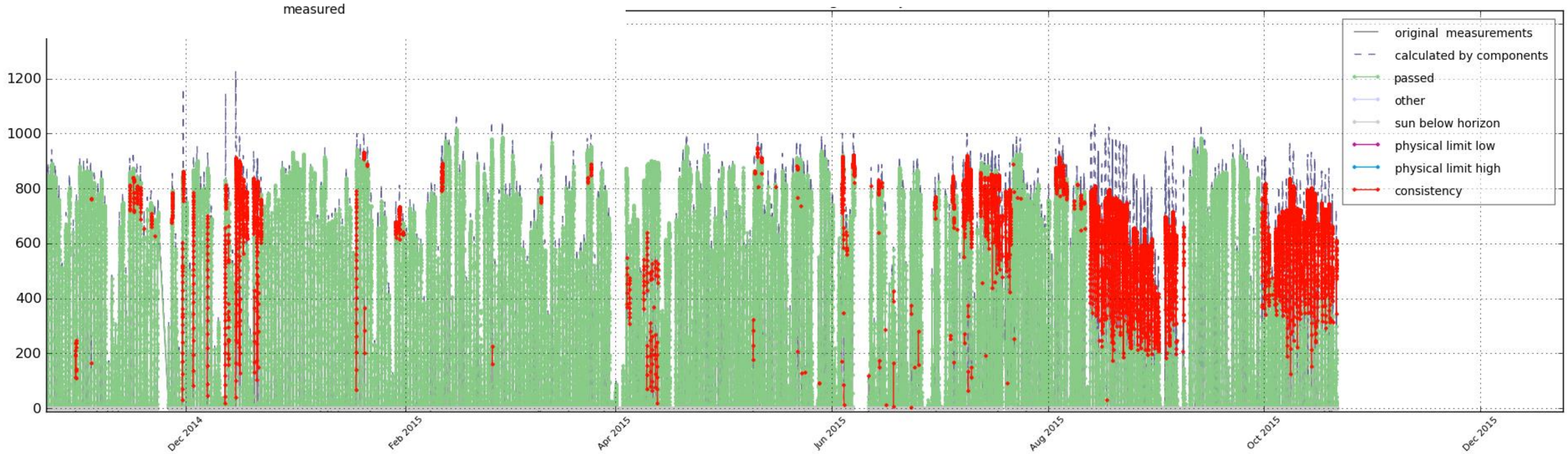
Rigorous quality assessment needed



- Data should be quality controlled before use

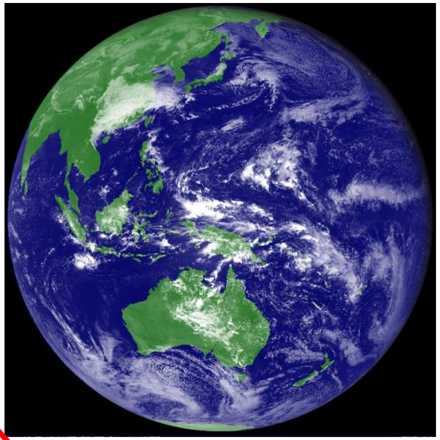


Acquiring solar and weather data

Ground measurements

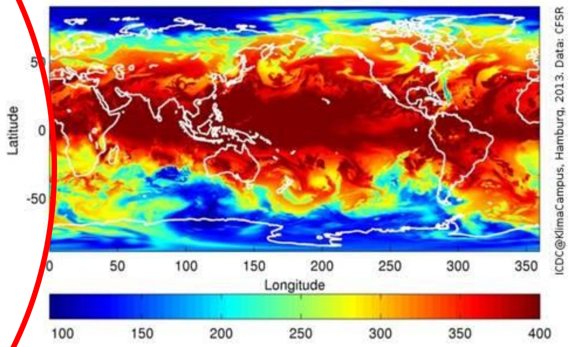
Source: CSP Services

Satellite models



Source: JMA

Meteorological models



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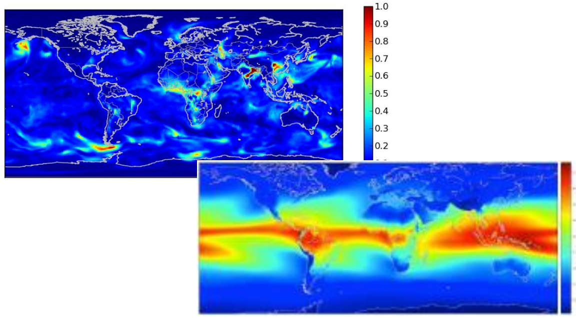
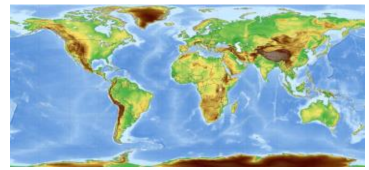
Solargis: satellite-based solar data

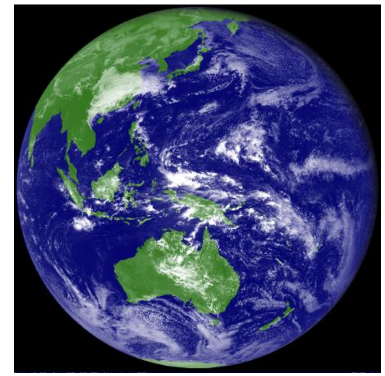
Atmospheric data

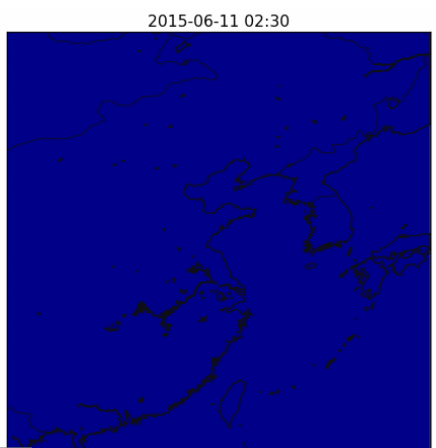


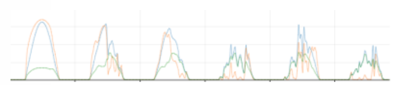
Terrain and other data



Satellite data

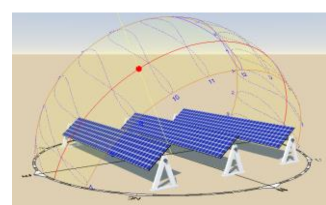






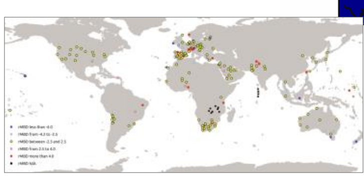
GHI, DNI, DIF

DNI
Direct Normal
Irradiance
(CSP power plants)



GTI
Global Tilted
Irradiance
(PV power plants)

Validation by solar measurements

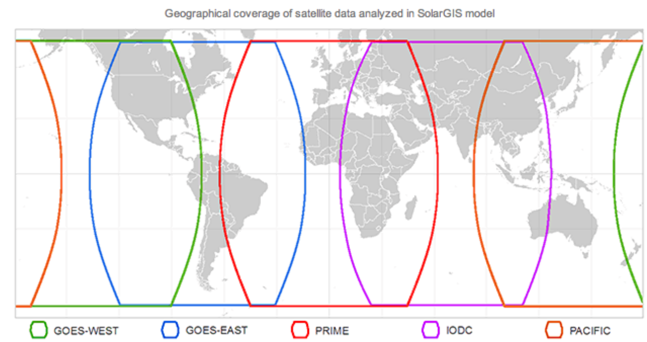


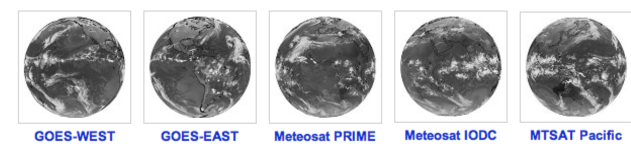
Source:: EUMETSAT, ECMWF, NOAA, SRTM, Solargis

Solargis: satellite-based solar model

Modelling cloud attenuation – geostationary satellites over China:

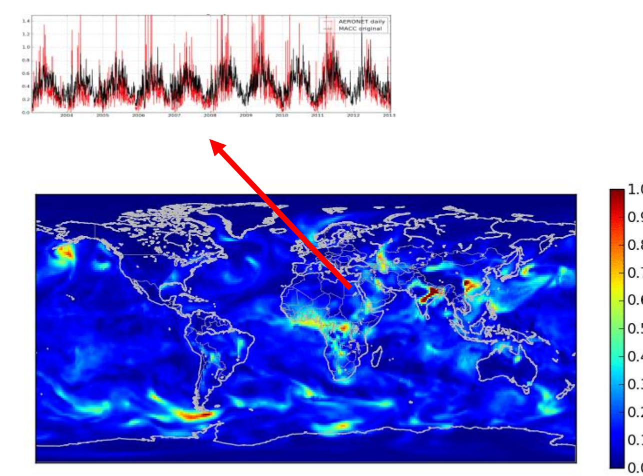
- Historical coverage
  - 1999 to the present (Meteosat IODC)
  - 2007 to the present (Himawari)
- Time resolution 10 and 30 minutes
- Grid spatial resolution approx. 4 to 7 km





Modelling clear-sky (cloudless) atmospheric conditions:

- Aerosols and water vapour from global models: MERRA-2, CFSR, CFSv2, GFS
- Digital Elevation Model SRTM-3



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Solar radiation: How satellite and measured data compare

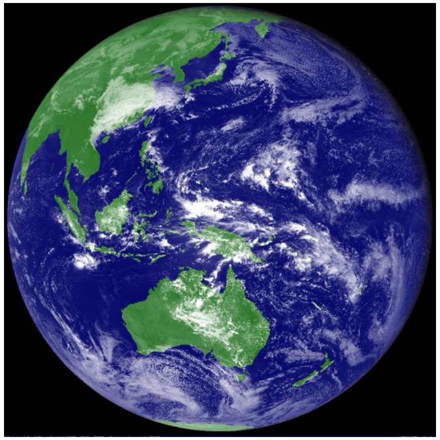
Solar radiation	Ground measurements (high-accuracy instruments)	Satellite models
Advantages	More accurate	Available for any site Historical and recent No gaps
Limitations	Operation and maintenance Quality control Price	Imperfections of models and input data

Acquiring solar and weather data

Ground measurements

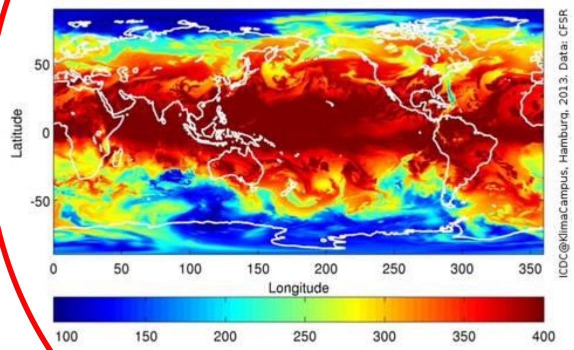
Source: CSP Services

Satellite models



Source: JMA

Meteorological models



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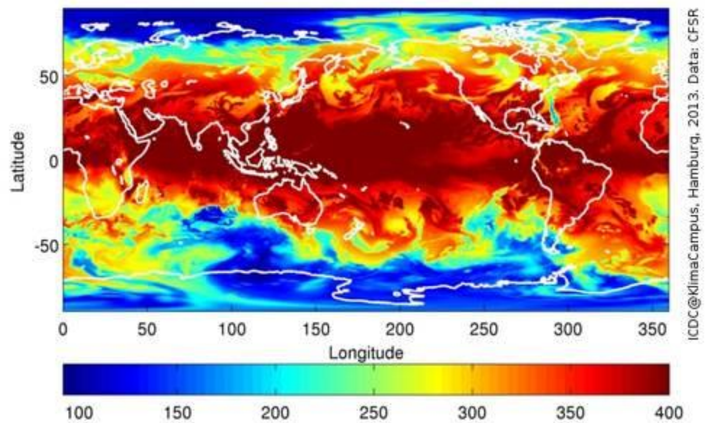
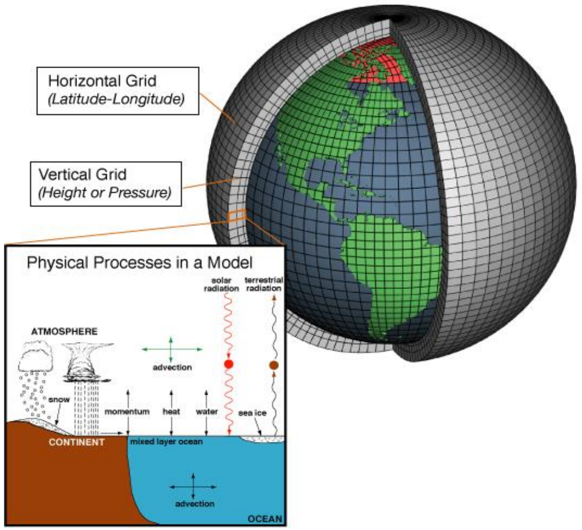
Deriving weather data from global meteorological models

- Rarely good measurements from nearby meteorological station are available
- Data from global meteorological models have to be used
  - Reanalysis: Historical meteorological data: CFSR, CFSv2, MERRA-2
  - Forecasts: IFS, GFS, GEOS5



Source: NOAA

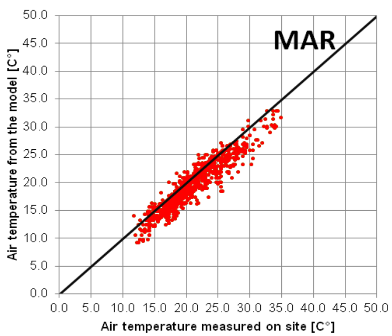


Source: NOAA

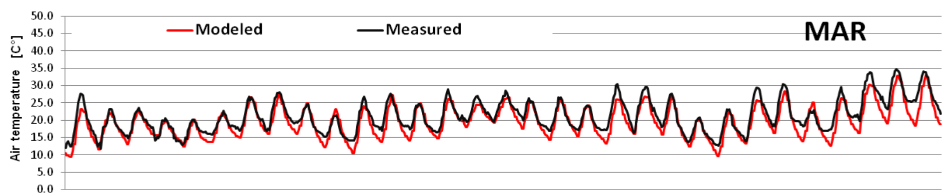
Deriving weather data from global meteorological models

Parameters that can be derived from meteorological models for any location

- Air temperature
- Wind
- Humidity
- Precipitable water
- Etc …



- Models represent regional weather conditions rather than local microclimate
- Therefore the data has to be postprocessed



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Difference model - measurements

Factors that determine the difference between the model and measurements

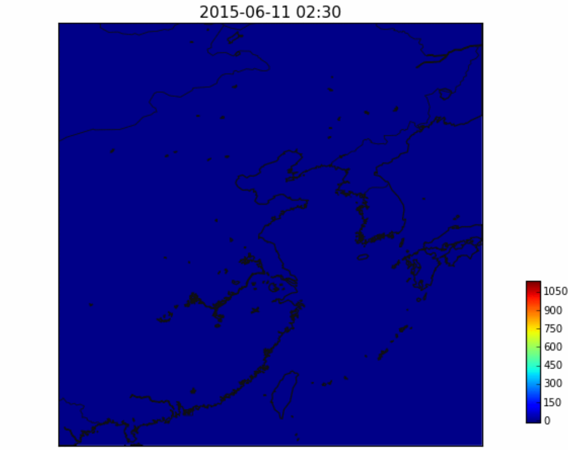
Models

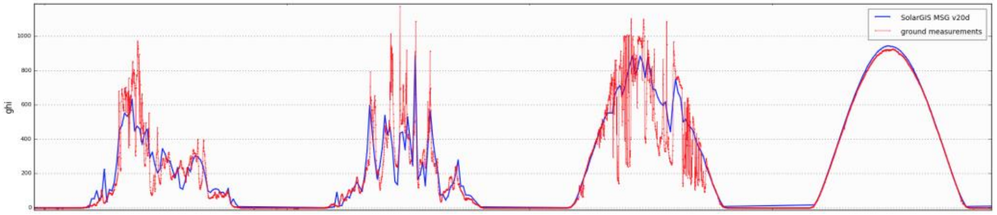
- Mathematical and algorithmic formulation of models
- Input data sets (satellite, weather models, etc.)

Solar monitoring instruments*

- Accuracy of sensors
- Maintenance and calibration of the instruments
- Quality control of the measured data

** For model validation, we use high quality measurements at high time resolution*





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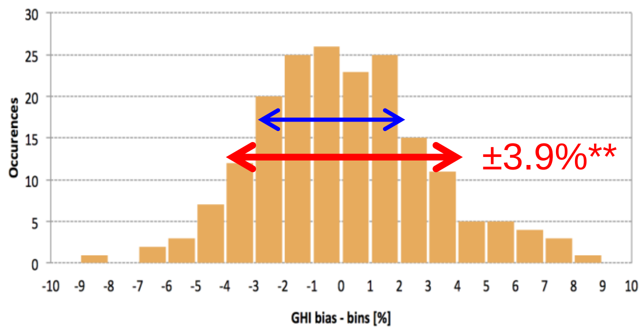
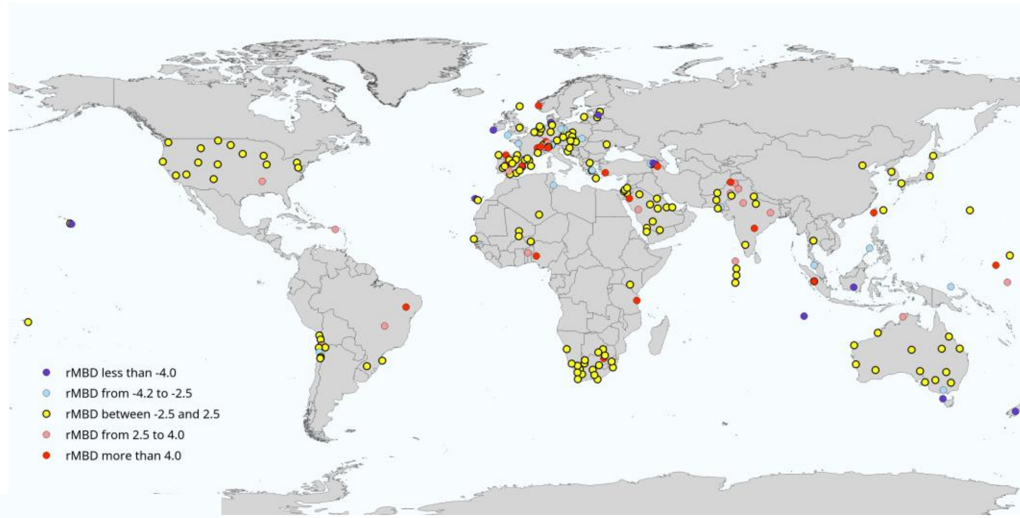
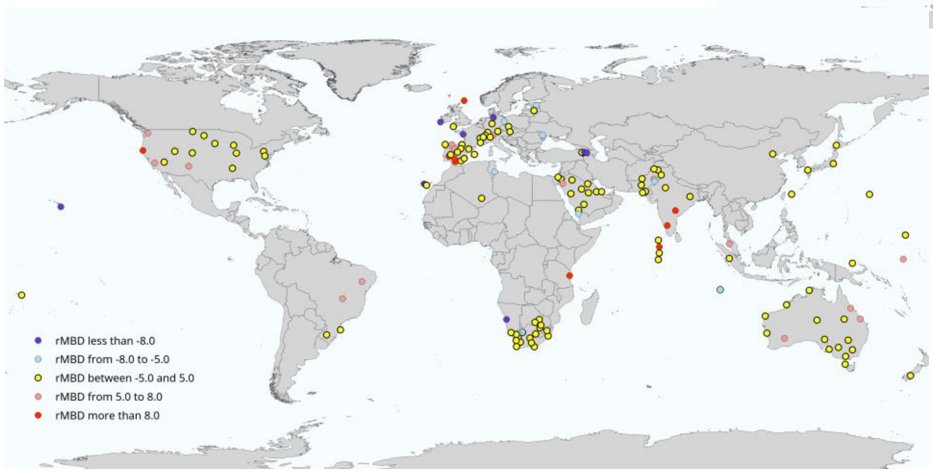
Solargis uncertainty of yearly estimates

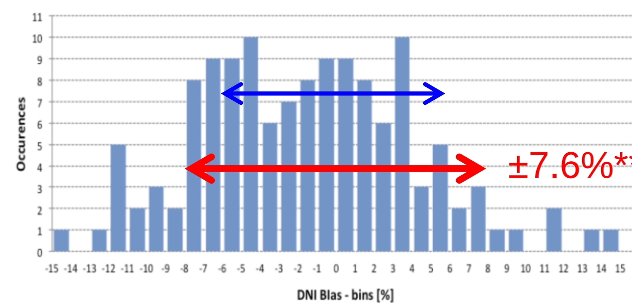
GHI: ±4% to ±10%







DNI: ±8% to ±18%

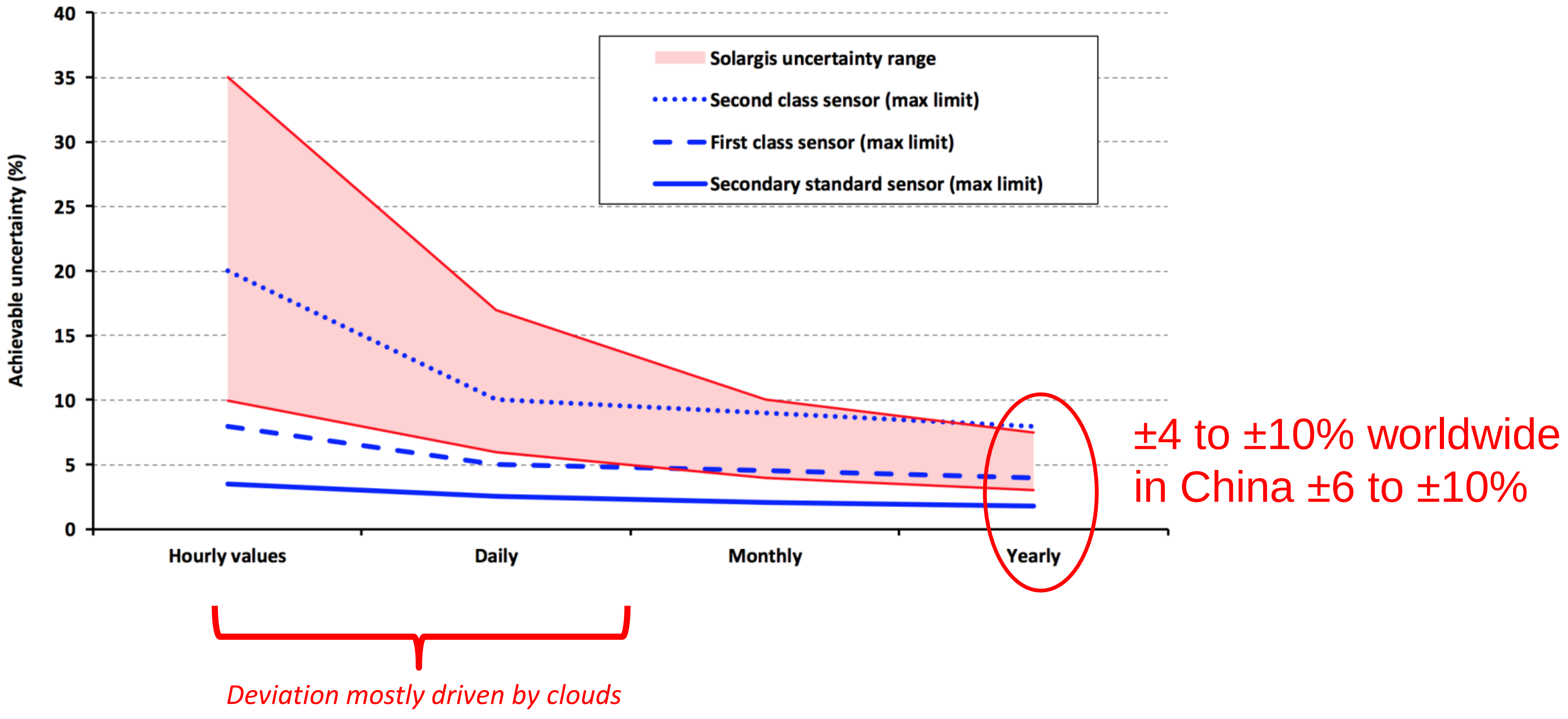


* 68.27% occurrence: standard deviation (STDEV) assuming simplified assumption of normal distribution

** 80% occurrence: calculated as 1.28155 STDEV − can be used for an estimate of P90 values

Source: SolarGIS

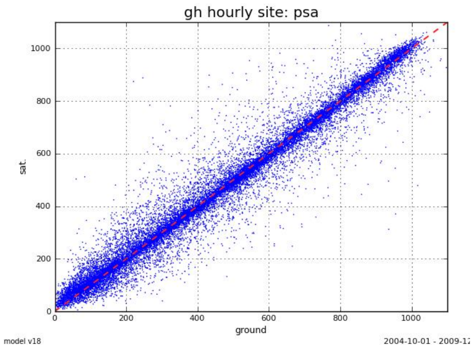
Uncertainty of satellite data and measurements



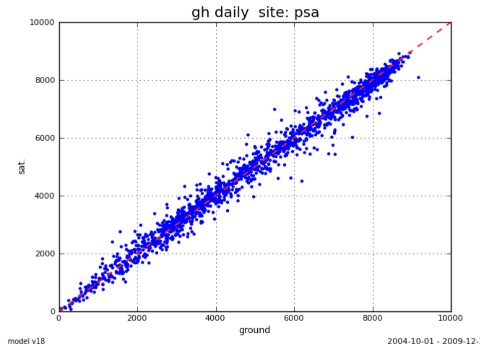
- Values are indicative, based on the analysis of 250+ sites
- Uncertainty for ground sensors considers that they are well maintained, calibrated and data are quality controlled

Uncertainty of satellite data and measurements

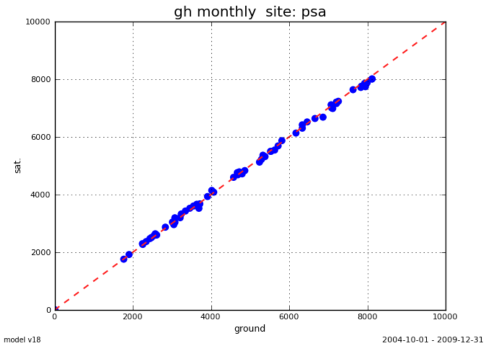
Plataforma Solar Almeria, Spain



Hourly values



Daily



Monthly

Discrepancy mostly driven by clouds

Satellite data is comparable to ground measurements for monthly and yearly aggregated values

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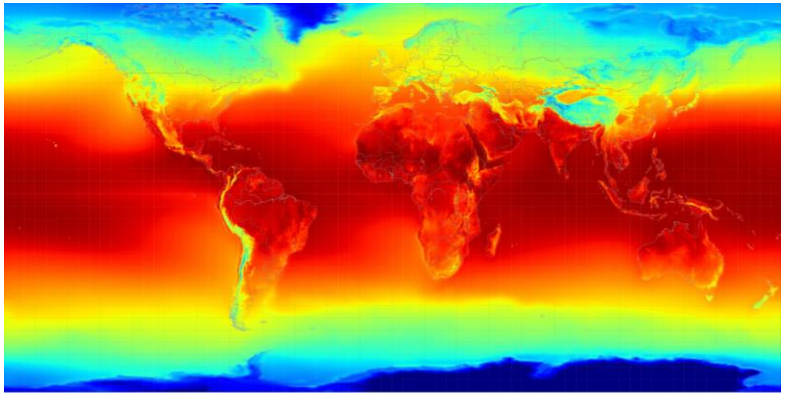
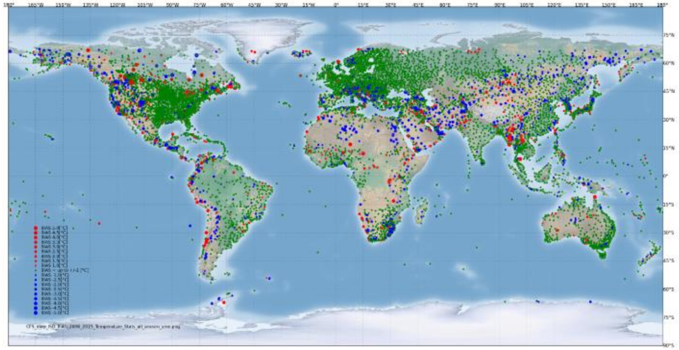
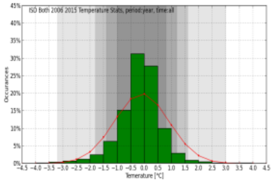
Validation of air temperature

High resolution air temperature derived from global meteorological model and validated by meteorological measurements



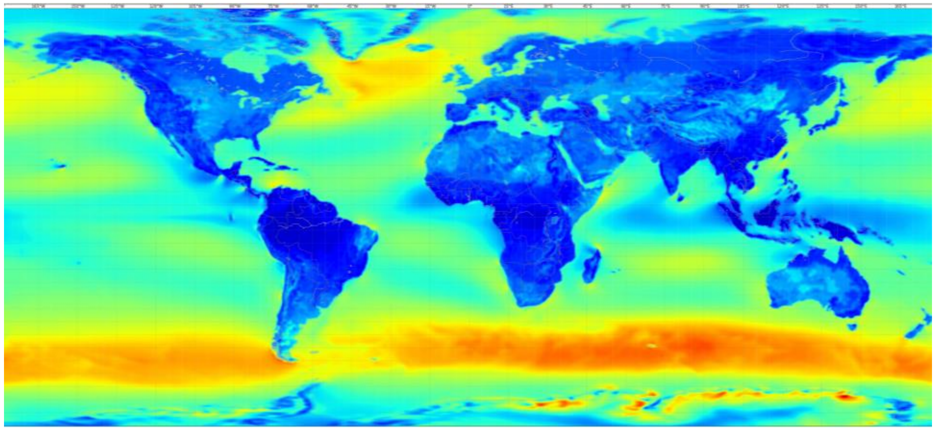
Bias



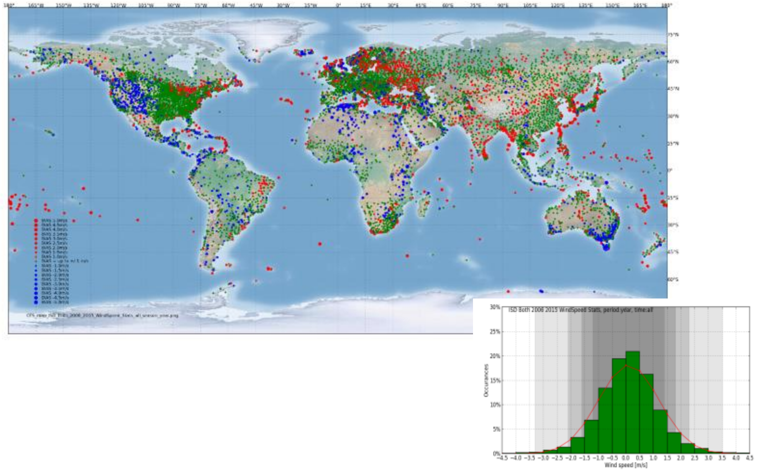


		average	std dev.	P80	P90	P95	P99
	24h	-0.1	1.0	0.9	1.3	1.7	3.1
BIAS [°C]	day-time	0.1	1.0	0.9	1.3	1.7	3.2
	night-time	-0.6	1.4	1.7	2.3	3.0	4.9
	hourly	2.4	-	2.9	3.4	3.9	5.8
RMSE [°C]	daily	1.7	-	2.1	2.6	3.1	5.0
	monthly	0.8	-	1.1	1.5	2.0	3.6

Validation of wind speed



Bias



		average	std dev.	P80	P90	P95	P99
BIAS [m/s]	24h	0.1	1.1	1.3	1.7	2.2	3.4
	day-time	-0.1	1.1	1.3	1.8	2.2	3.4
	night-time	0.3	1.2	1.4	1.9	2.5	3.9
RMSE [m/s]	hourly	2.0	-	2.3	2.8	3.3	4.6
	daily	1.4	-	1.8	2.3	2.8	4.1
	monthly	0.9	-	1.3	1.8	2.3	3.5

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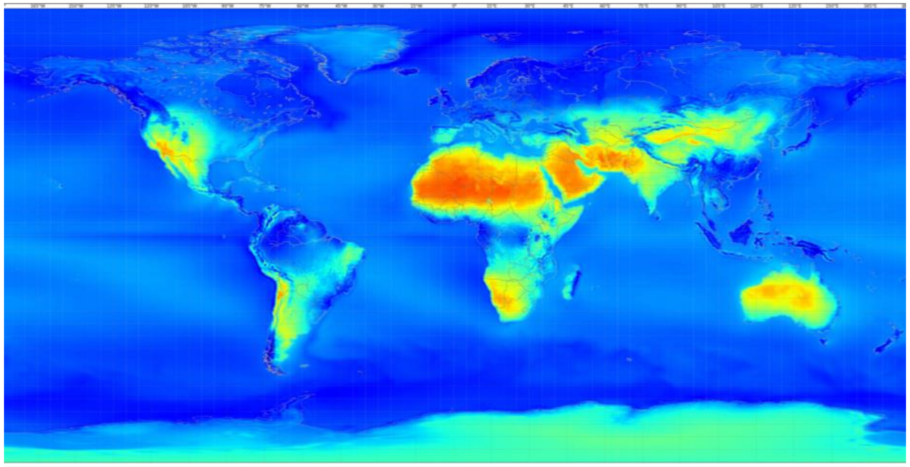
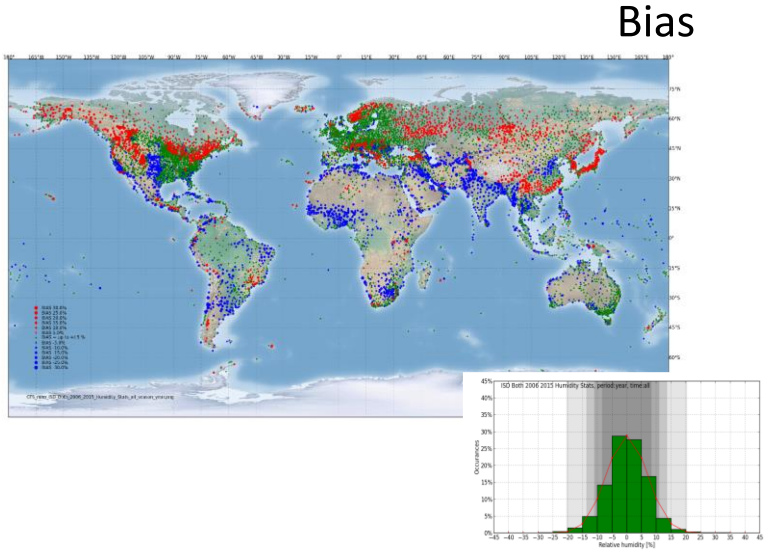
Validation of relative humidity





		average	std dev.	P80	P90	P95	P99
BIAS [%]	24h	0	7	8	11	14	20
	day-time	0	7	9	12	15	22
	night-time	1	7	9	12	14	21
RMSE [%]	hourly	15	-	18	20	22	28
	daily	12	-	15	17	19	25
	monthly	8	-	11	13	15	21

Content

- Data needed for PV simulations
- Old and modern data approaches
- Solar and weather data acquisition
  - Meteorological measurements
  - Satellite-based solar models
  - Meteorological models
- Validation of solar radiation data
- Validation of meteorological data
- PV power forecasting
- Integrated data flow for continuous PV simulations

Value of forecasting

Maximizing the value of solar power
Reducing the costs of power generation

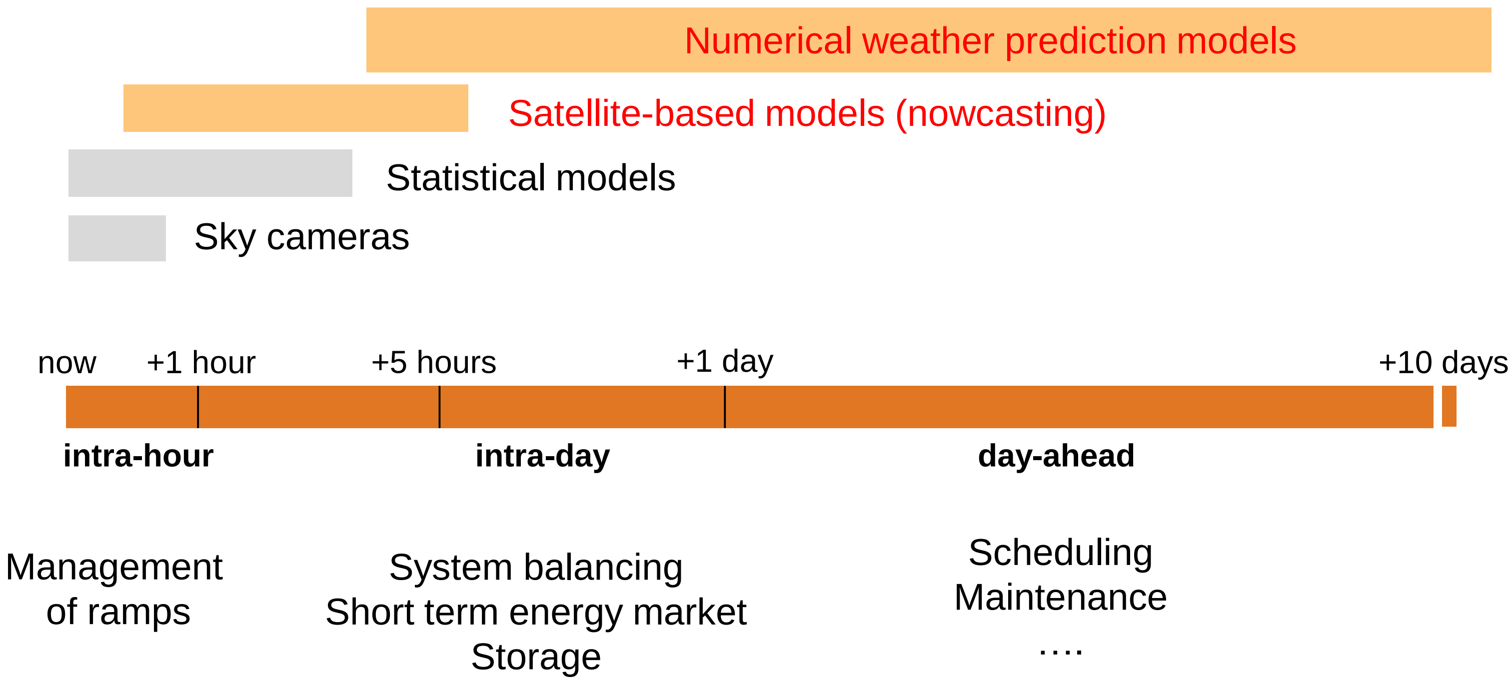
Operator

- Reduction of curtailment, maximized utilization of solar electricity
- Trading
- Better management of solar hybrid solutions

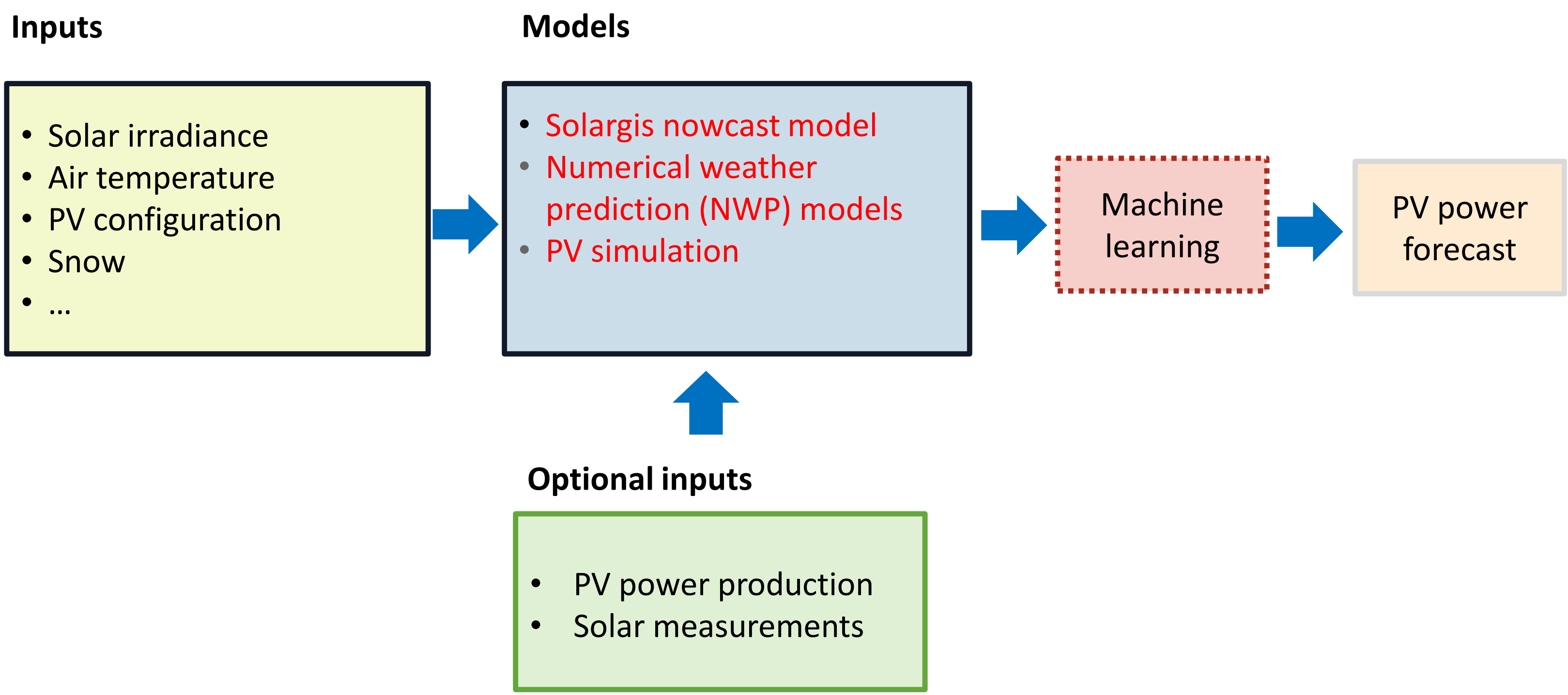
Utility

- Maximizing the share of renewables
- Better integration with other power generation sources
- Minimising the operating reserve capacities

Forecasting approaches



Forecasting PV power forecast



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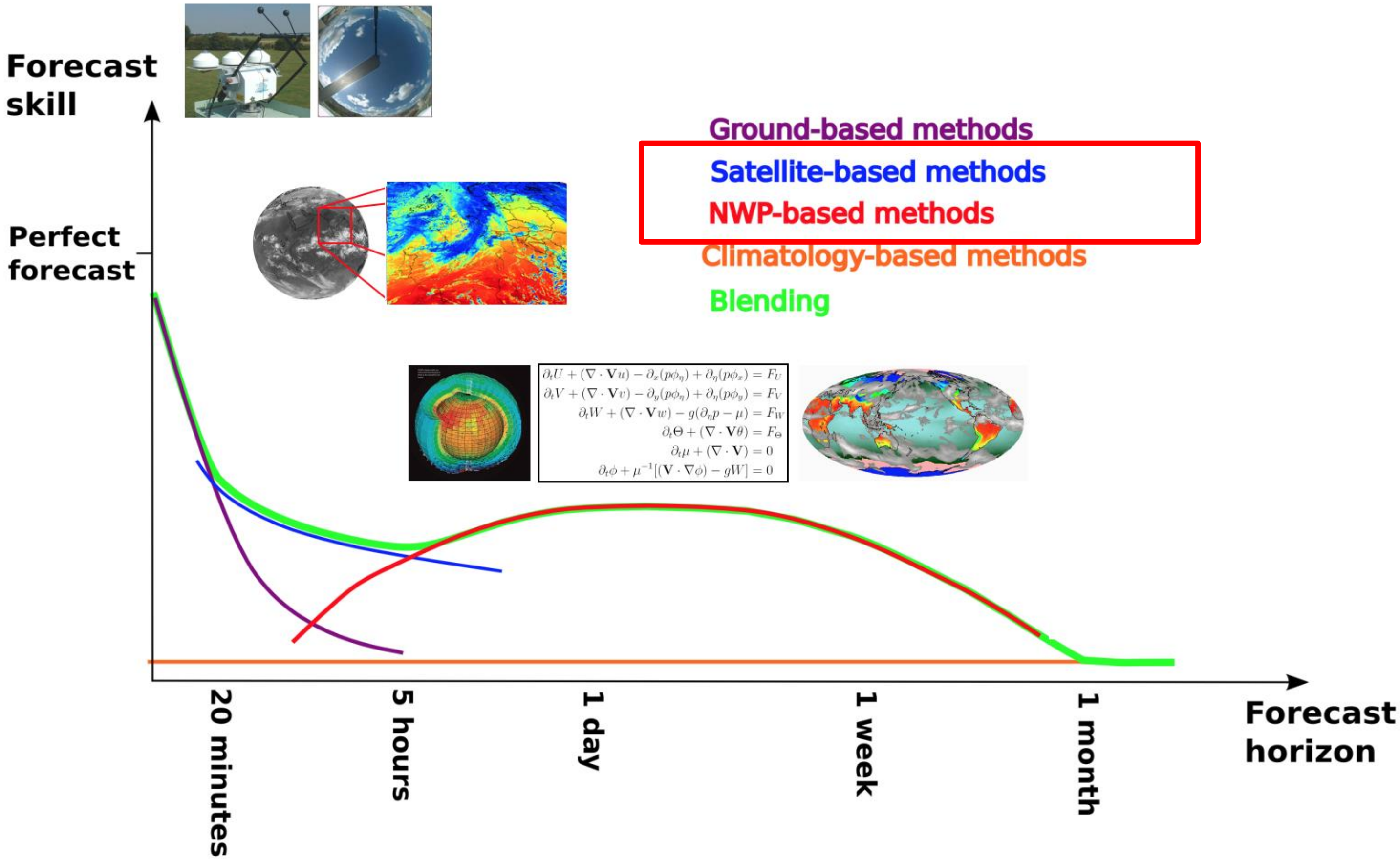
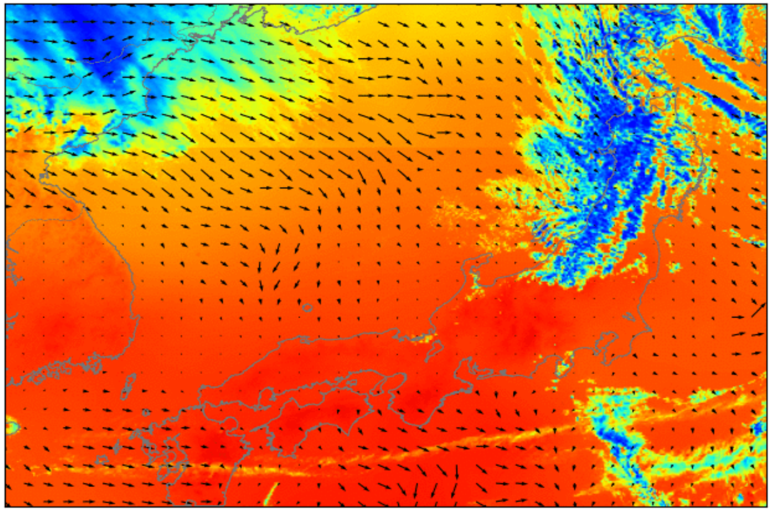
Solar forecast: combination of models



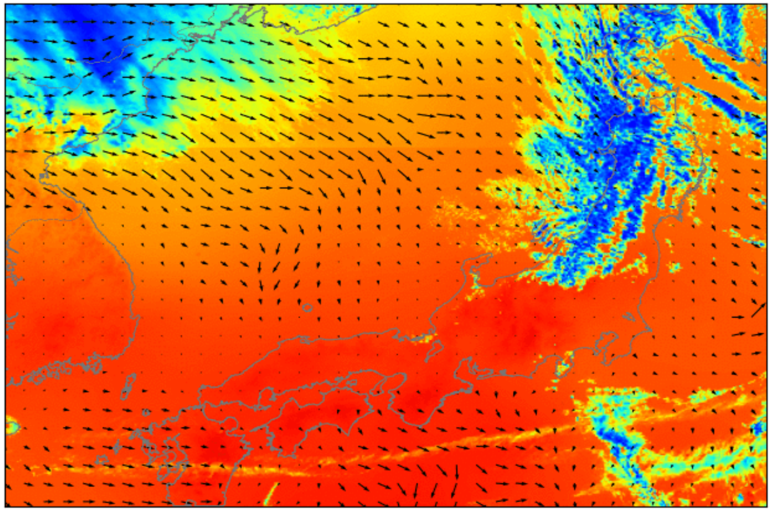
Satellite-based nowcasting

- Cloud motion vectors derived from satellite images
- Forecast time horizon: 0 to 5 hours

Solar radiation computed
from satellite data (one day later)



Nowcasting output



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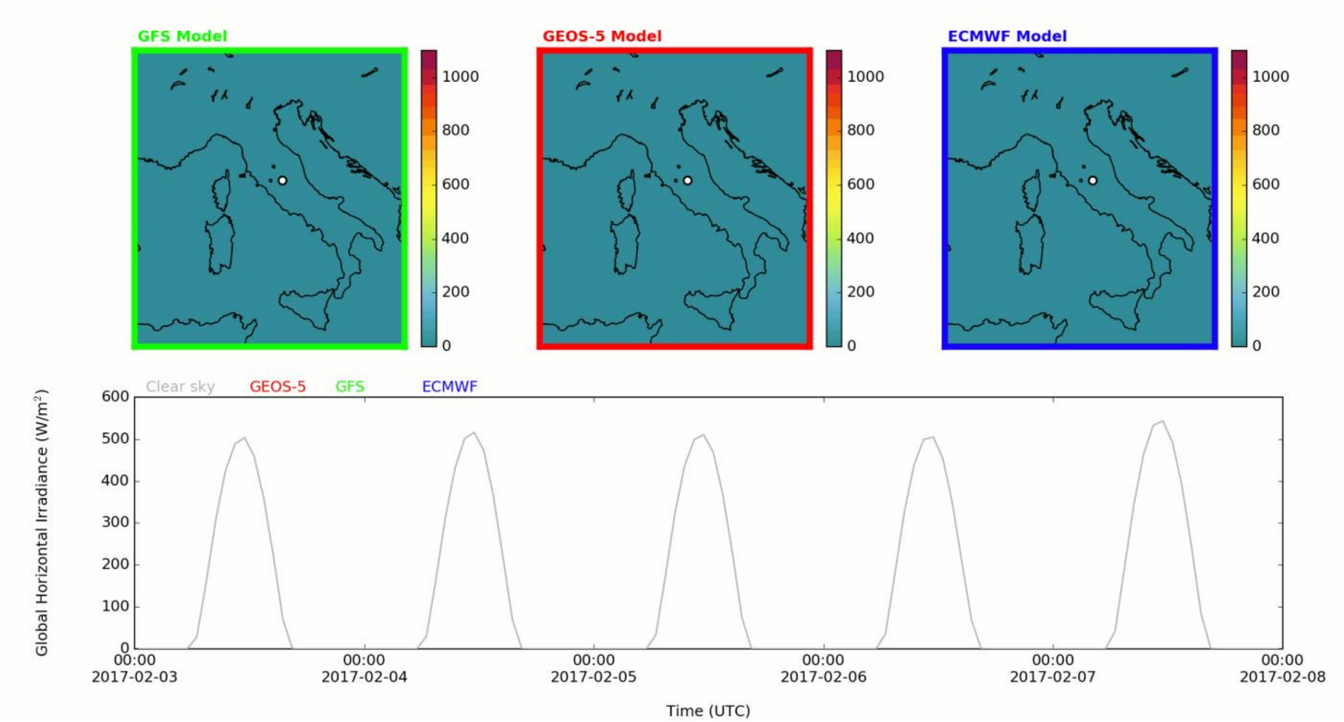
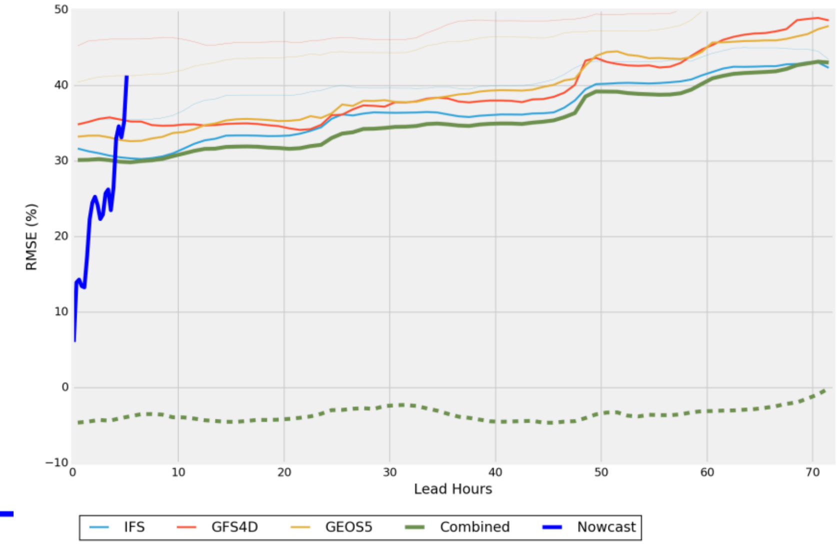
NWP forecasts: Day ahead

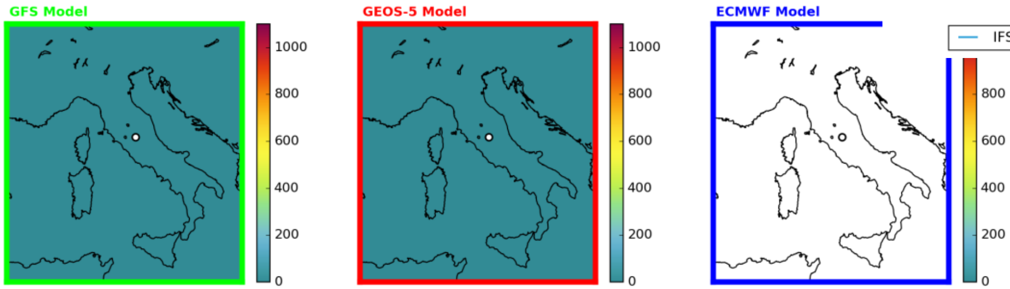
- Forecast based on postprocessing of outputs from Numerical Weather Prediction (NWP) models
- Forecast output from several NWP is often used
- Forecast time horizon: 0 to 10 days

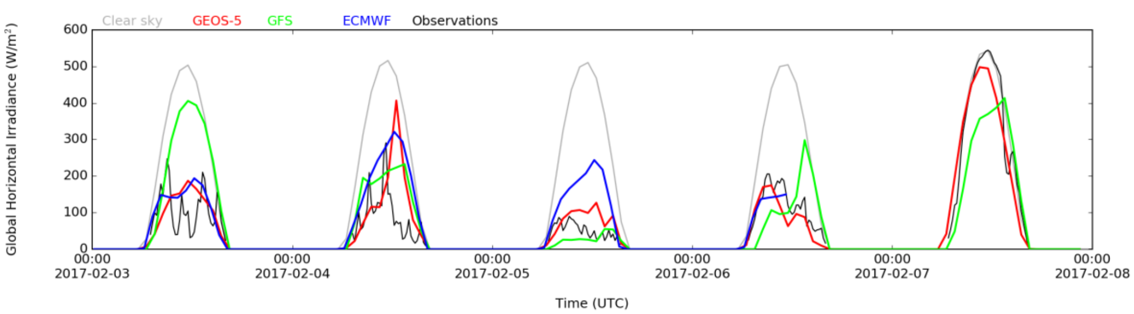


NWP forecasts: Day ahead



Comparing day-ahead forecast from three models with satellite-derived GHI data (Italy)





Accuracy analysis Bratislava, Slovakia

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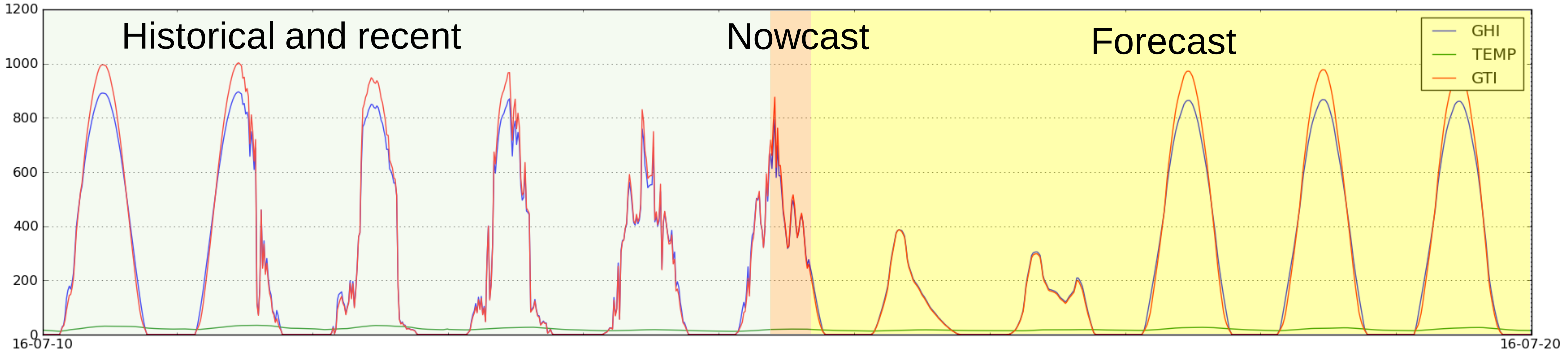
Conclusions

Seamless integration of Solargis data flow for PV power simulations:

- Updated data is available at any time:
  - **Historical**: for project development and due diligence
  - **Recent**: for PV monitoring and performance evaluation
  - **Forecast**: for trading and grid management
- Solar radiation, meteorological parameters, PV power output
- For any location, globally



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