Modelling and Measurement of Spectral Solar Irradiance at SIRTA: Applications to Photovoltaic Performance Studies

SIRTA
SITE INSTRUMENTAL DE RECHERCHE PAR TÉLÉDÉTECTION ATMOSPHÉRIQUE

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OBJECTIVES:

- To investigate SMARTS2 modelling model by comparing with measurements and develop applications.
- To understand the spectral effect on the electricity production of PV solar cell.

Instrumentation and Devices:

- EKO-MS700 Spectroradiometer: Spectral Irradiance Measurement
- Installed on 18-March-2015
- Wavelength Range: 350-1050nm
- Timestamp: every minute

- Kipp & Zonen CMP 22 Pyranometer: Solar Radiation Flux Density Measurement (W/m2)
- Installed in 2003
- Wavelength Range: 200-3600nm
- Timestamp: every minute

- PV1 Measurement include wind speed, POA irradiance, short-circuit current, open-circuit voltage.
- Joint collaboration between LMD, LPICM, LIMSI, GeePs
- Installed in December 2013

Introductions and Results:

Measurement:

SIRTA Server

Pyranometer | Spectroradiometer

SMARTS2 Model:

Input:
Aeronet Data

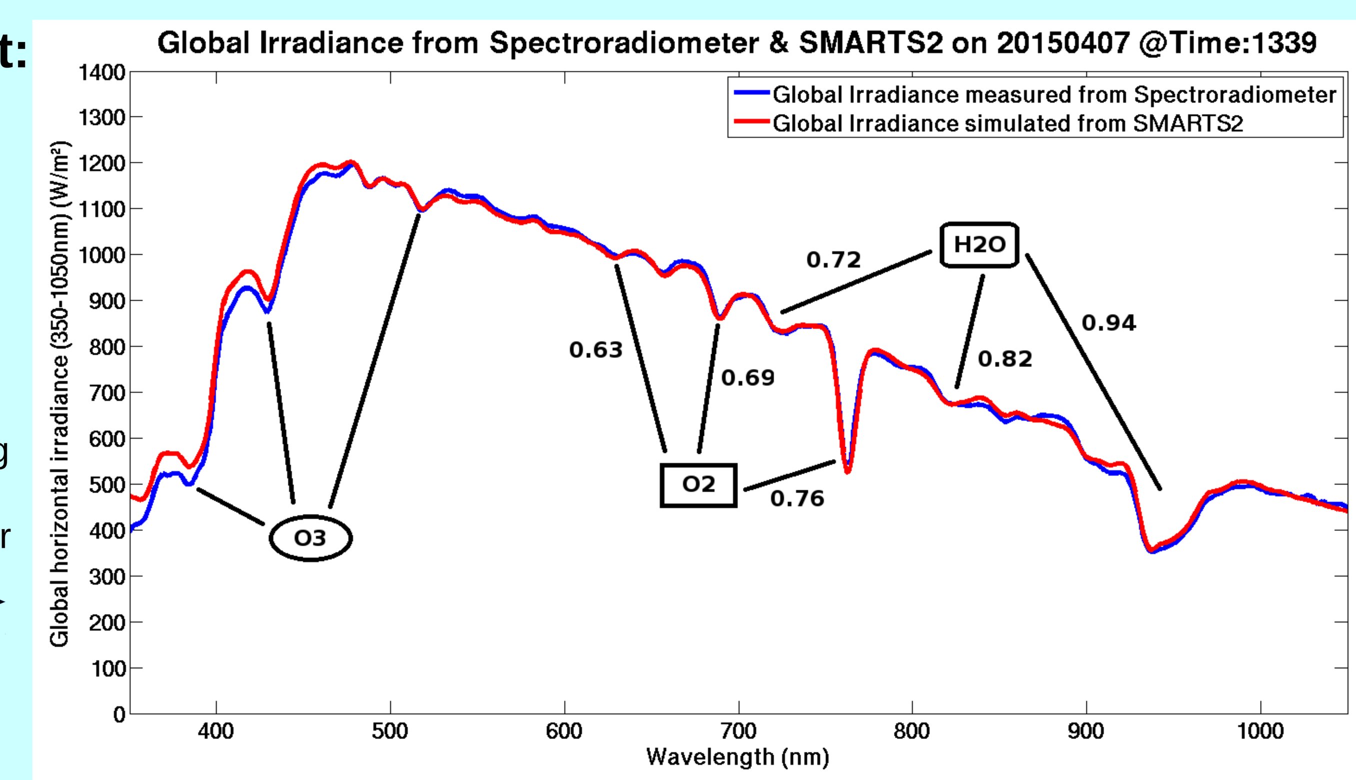
- Water Vapor
- Aerosol Optical Depth
- Solar Zenith Angle
- Etc......

SMARTS2:

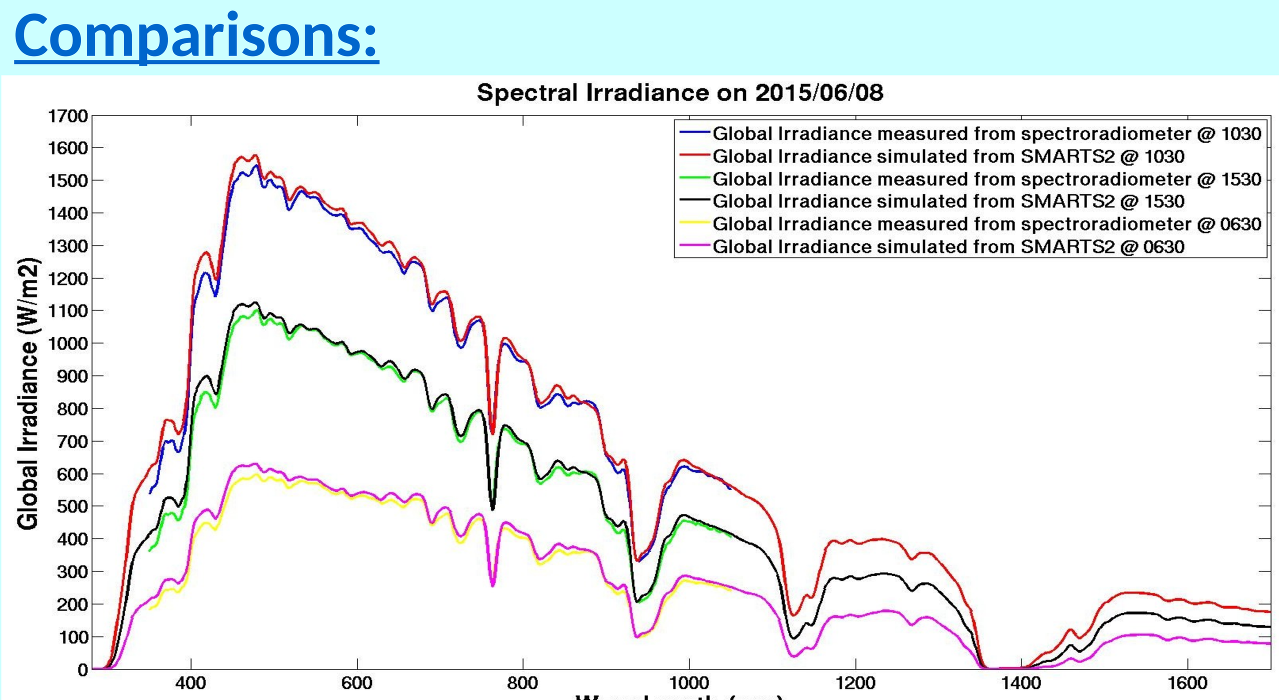
Simple Model of Atmospheric Radiative Transfer of Sunshine

Gaussian Smoothing for 10nm FWHM of Spectroradiometer

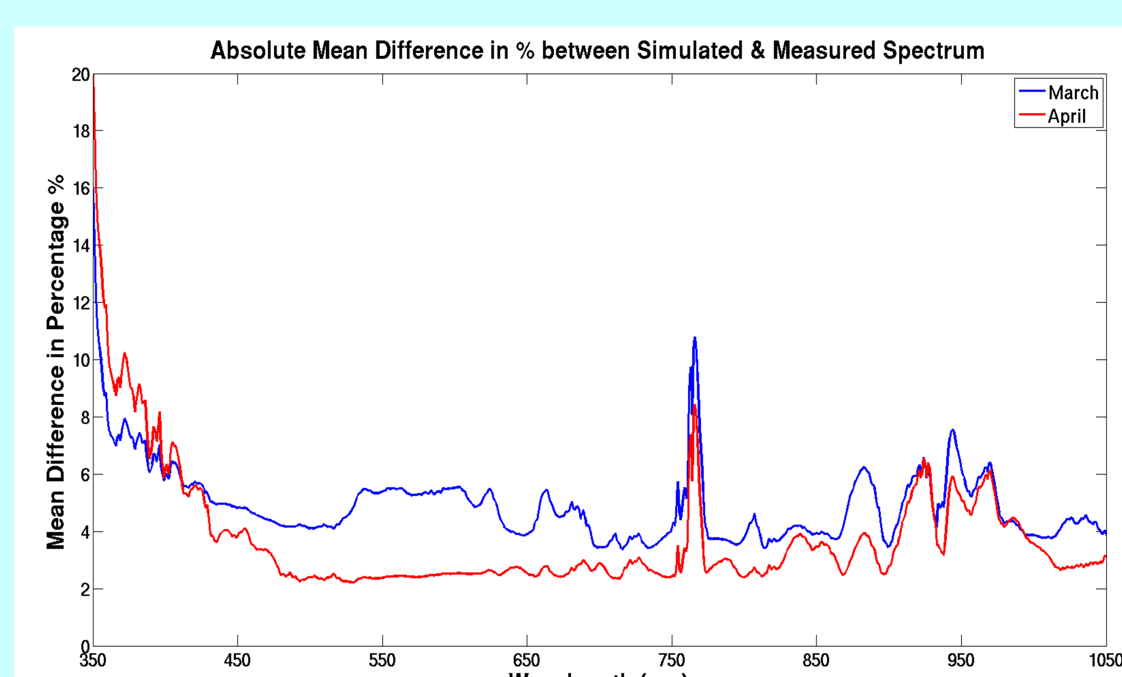
Output:



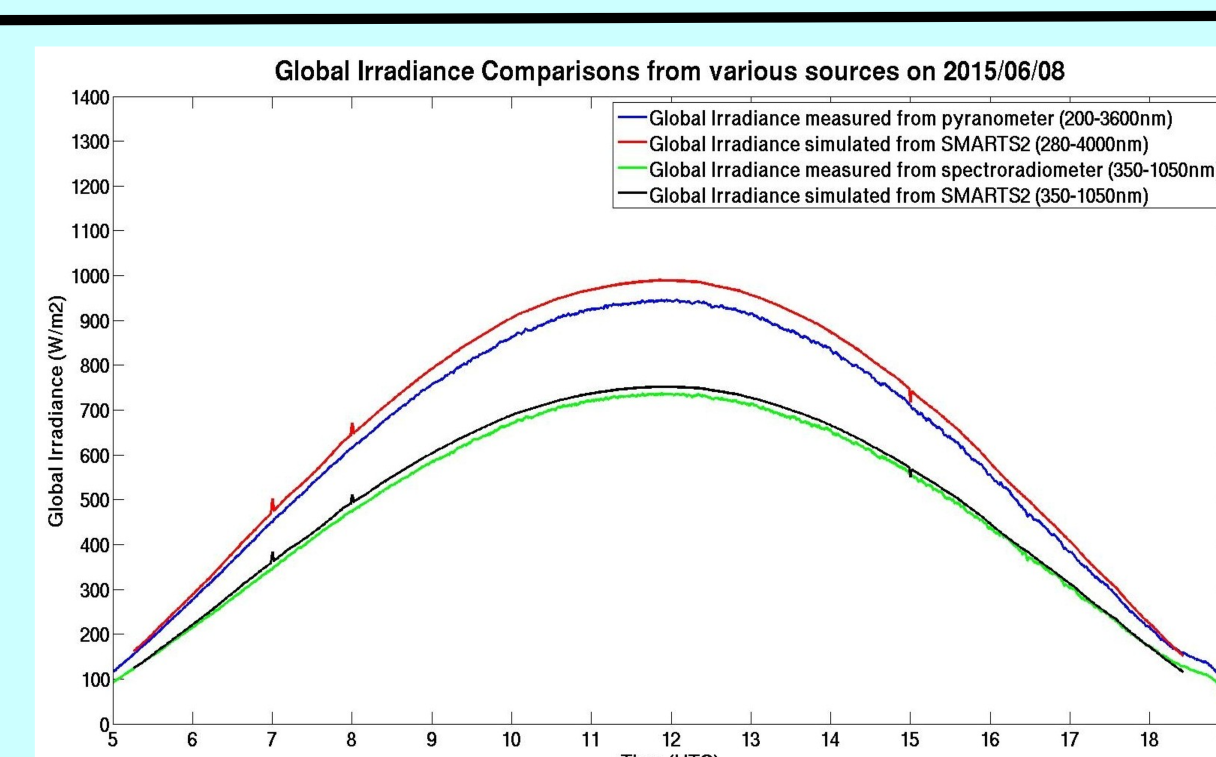
Comparisons:



- SMARTS2 allow us to simulate spectrum at different time and compare with the measurement
- From the spectrum we are able to know whether it is blue-rich or reddish light.



- Sensitivity test is carried out to check how well SMARTS2 performed by comparing with measurement.
- Graph above showed the absolute mean difference in % between simulated and measured spectrum.



- With integration of spectrum, the daily global Irradiance can be calculated.
- Prediction of global irradiance available is important as Irradiace has direct impact on the output current of PV panel.

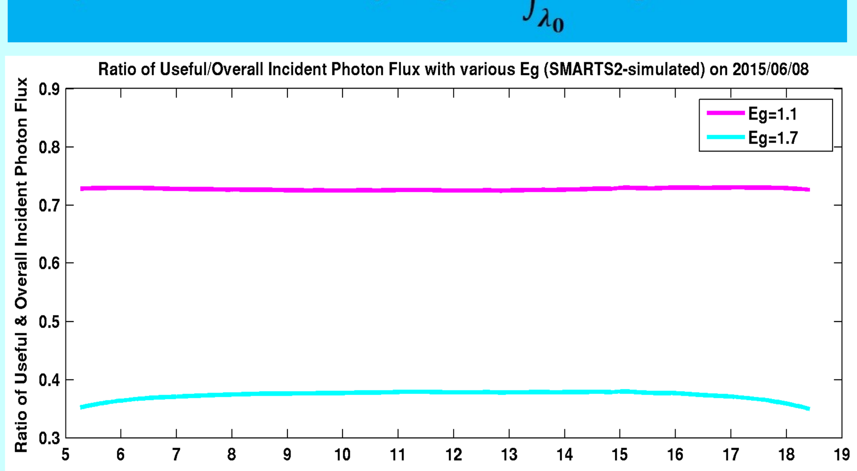
Spectral Response & Irradiance Effect:

Useful Photon Flux Ratio:

Equation:

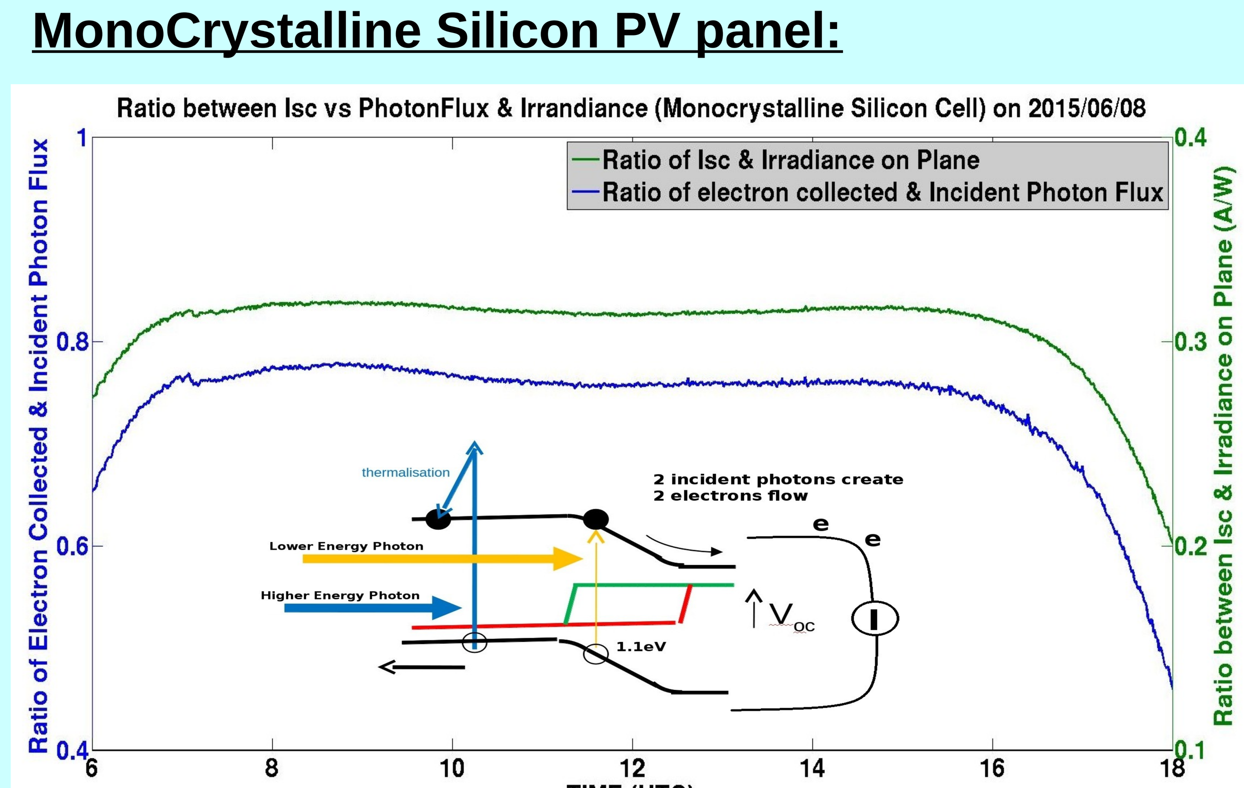
$$\text{Photon Flux } q(\lambda) = \frac{\text{Irradiance } P(\lambda)}{\text{Energy } (\lambda)} = \frac{\lambda * P(\lambda)}{\hbar * c}$$

$$\text{Useful Photon Flux } \phi(Eg) = \int_{\lambda_0}^{\lambda < \frac{hc}{Eg}} q(\lambda)\, d\lambda$$

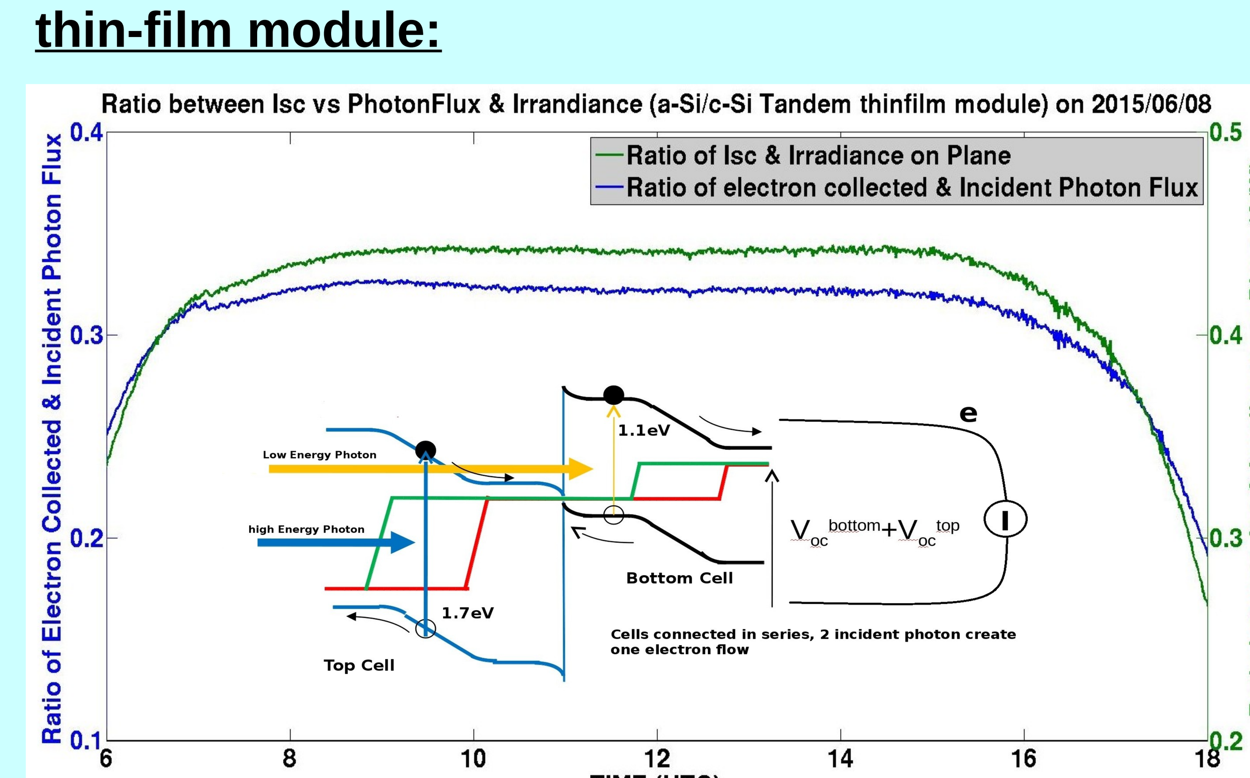


- With the spectral distribution information, we can derive the ratio of useful photon flux which is actually higher than the bandgap and can be absorbed.

MonoCrystalline Silicon PV panel:



Amorphous-microcrystalline silicon "tandem" thin-film module:



- With the ratio of photon flux that possess higher energy than the bandgap, we can analysis how many free electrons are created and collected due to each useful photon.
- Ratio of electron collected/Incident photon and Ratio of Short-Circuit Current/POA Irradiance are plotted for both types of PV panel, The shape of the graph shows that the current is dependable on the ratio of useful photon flux.

Conclusion:

In a nutshell, SMARTS2 model can simulate spectral irradiances well with an average error around 3% as compared with spectroradiometer measurement (except for the UV & absorption material part). With SMARTS2 model which provide large range of wavelength simulation (280-4000nm), together with SIRTA platform, we are able to investigate the effect of spectral irradiance on photovoltaic performance. This allow us to calculate and predict the output electricity of various PV panels.

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