Geometric Spectral Albedo

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PVMD
Delft University of Technology

16th of Sep 2019

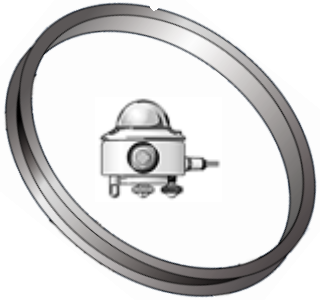
BiFi Workshop, Amsterdam

TU Delft

Irradiation components

- Direct

- Diffuse



- Albedo

Irradiation components

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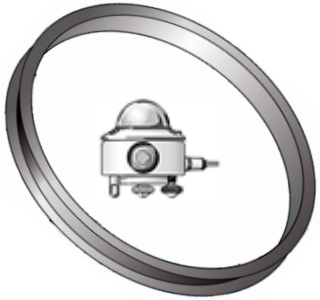
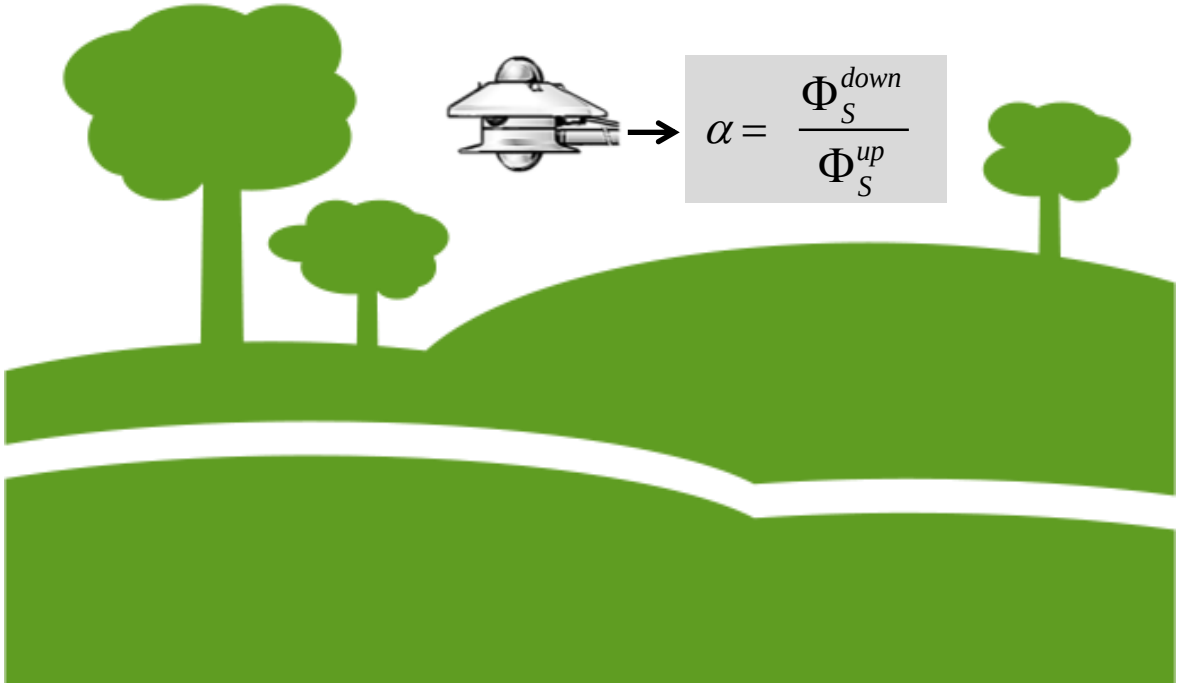


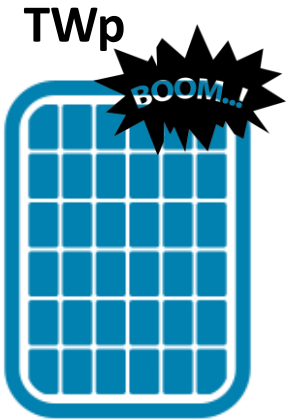
- **Albedo**

Albedo

- The ratio between reflected upwelling radiation and the global downwelling radiation incident at the measurement surface.



Importance of albedo for PV



- TWp PV era is coming…
- 20% share for bifacial by 2022.
- Bifaciality is an option to increase the PV energy yield with low additional cost.
- For bifacials, contribution of albedo component of sunlight becomes more significant.

Up to 30% more energy for Amsterdam and even more

Depends on
1) bifacial factor
2) albedo value

International Technology Roadmap for Photovoltaic, 9th edition, (2018).
R. Kopecek and J. Libal, *Nature Energy*, **3**, (2018).
G. J.M.Janssen, et. al., *Energy Procedia*, **77**, (2015).

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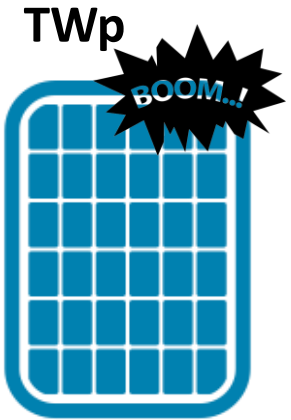

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Accurate albedo modelling ⟶ Less error in yield prediction

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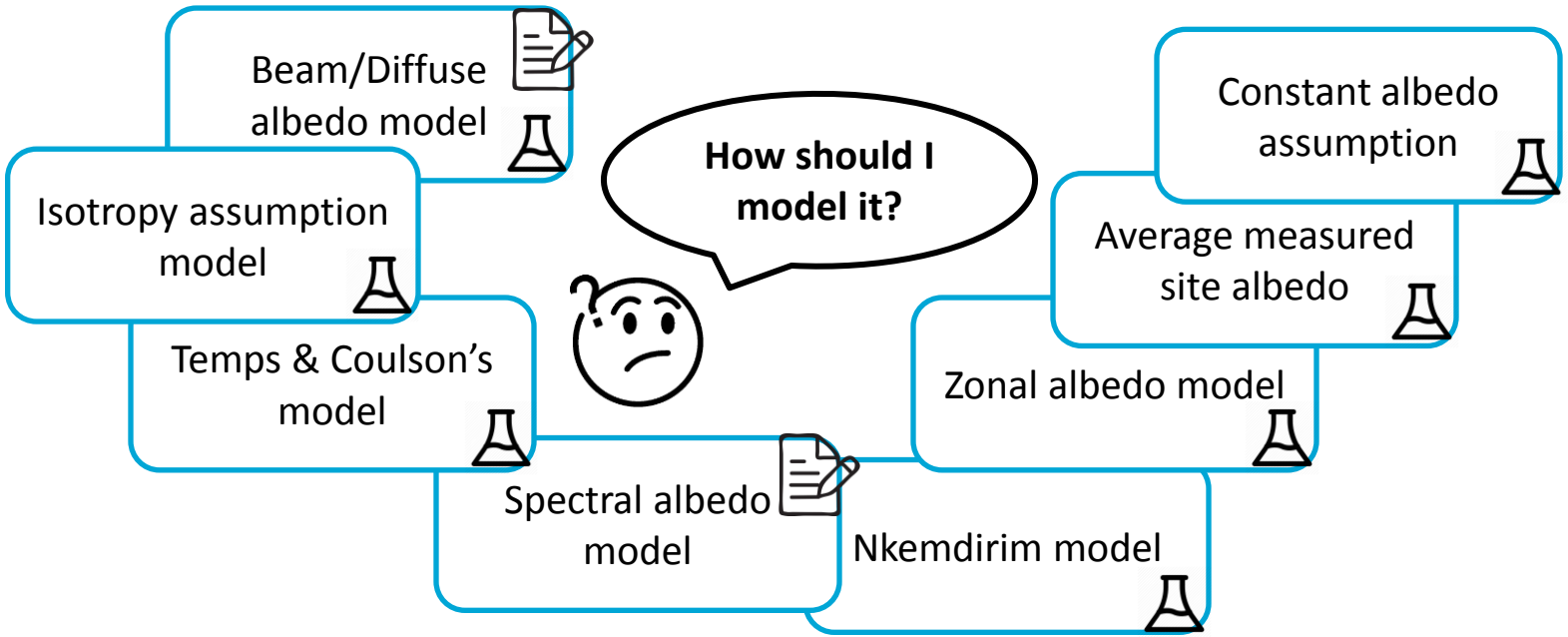
Previous models



B. Y. Liu and R. C. Jordan, *Solar Energy, **7**, (*1963).
P. Ineichen, et.al., *Solar Energy, **39**, (*1987).
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L. C. Nkemdirim, *Journal of Applied Meteorology, **11**,* (1972).
C. Gueymard, *Solar Energy, **38**, (*1987).
J. E. Hay, *Renewable energy*, **3**, (1993).
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A. Baldridge, S. Hook, C. Grove, and G. Rivera, *Remote Sensing of Environment*, **113**, (2009).

Complexity in albedo modelling

- **Whatever** is in an environment may influence albedo and the environment is changing all the time, so does albedo.
- Light source condition is influential.
- Previous models are neither right nor wrong. They are incomplete.

Dependency of albedo on many factors makes it a huge challenge to fed all the influential parameters into one coherent model.

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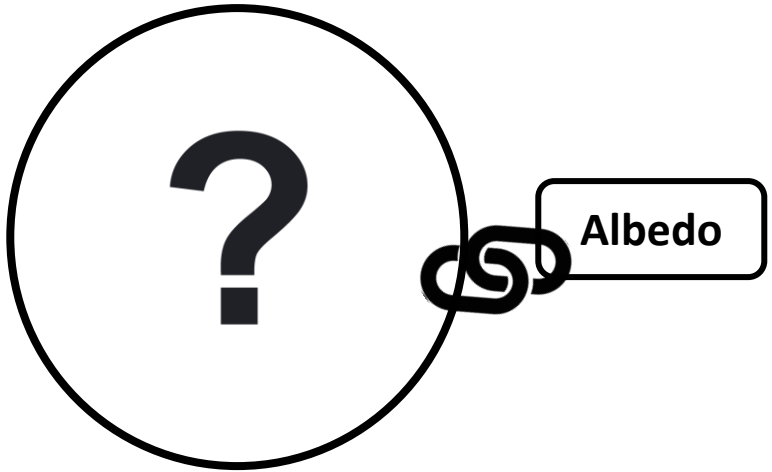
Main influential factors

- Surrounding environment can be explained by two main features:
  - Material
  - Geometry
- On top of that, to model albedo, we have to consider light source features as well.



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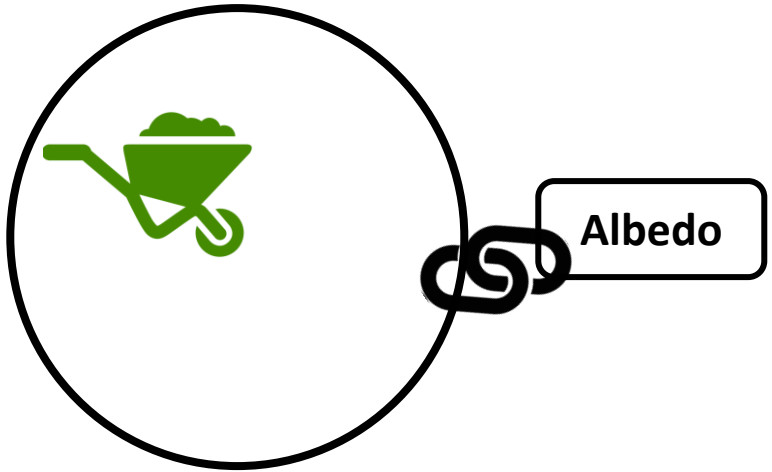

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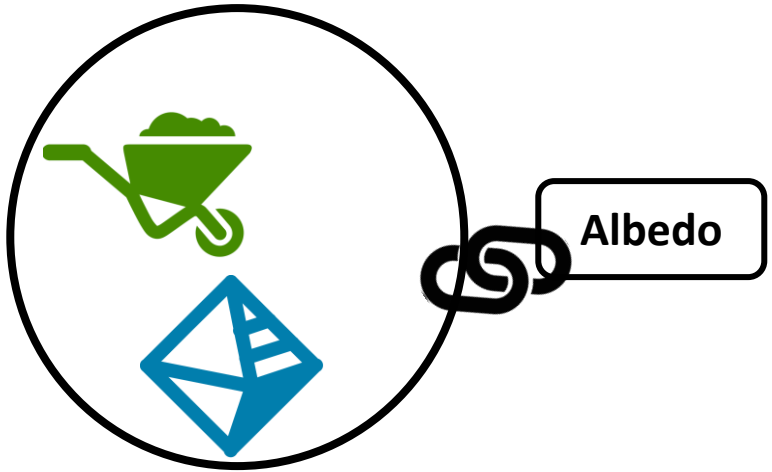

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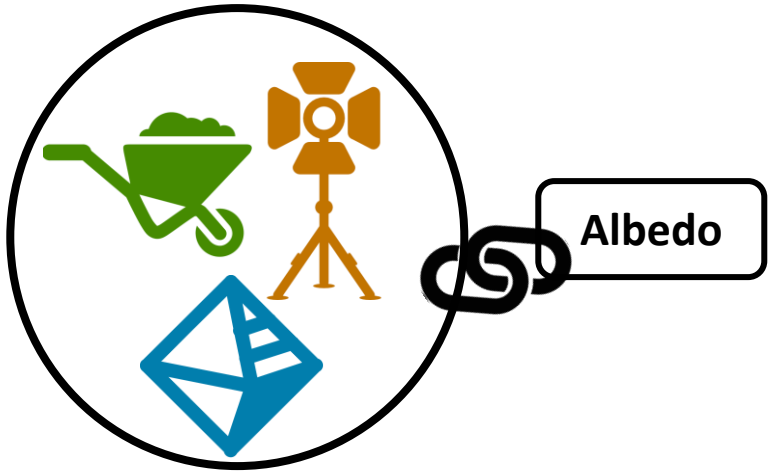
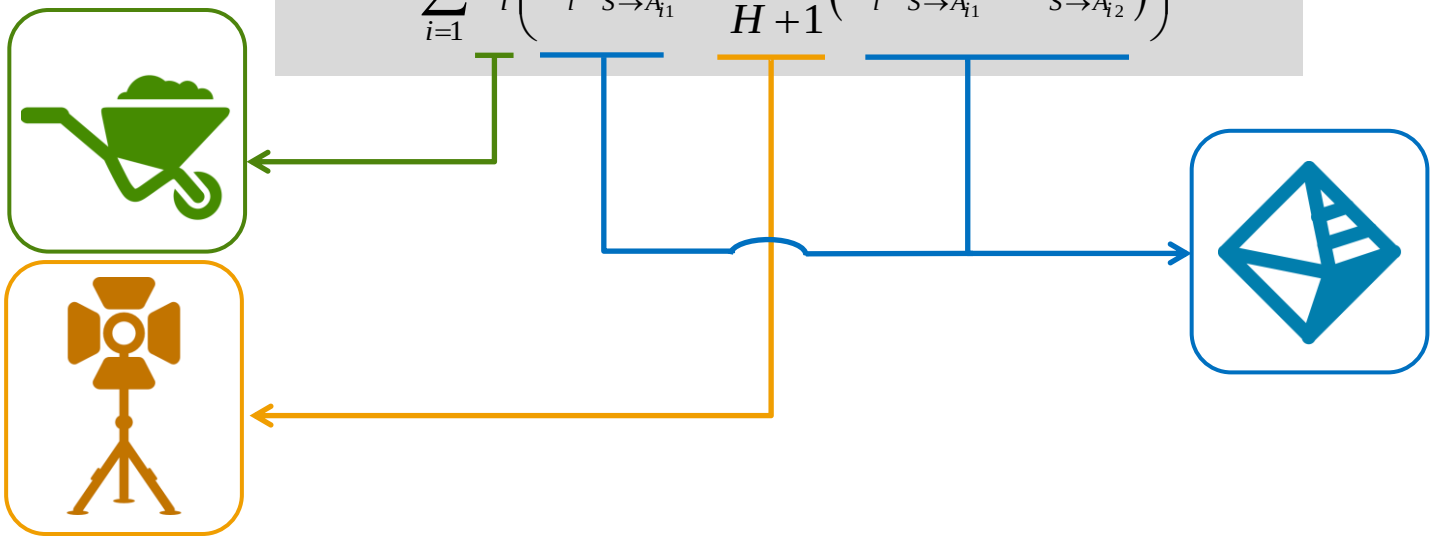


Coherent albedo model

- Now lets put all of them together:

$$\alpha = \sum_{i=1}^{i=N} R_i \left(C_i F_{S \to A_{i1}} + \frac{1}{H+1} \left(C_i' F_{S \to A_{i1}} + F_{S \to A_{i2}} \right) \right)$$



H. Ziar, et al., *Applied Energy*, **255**, (2019)

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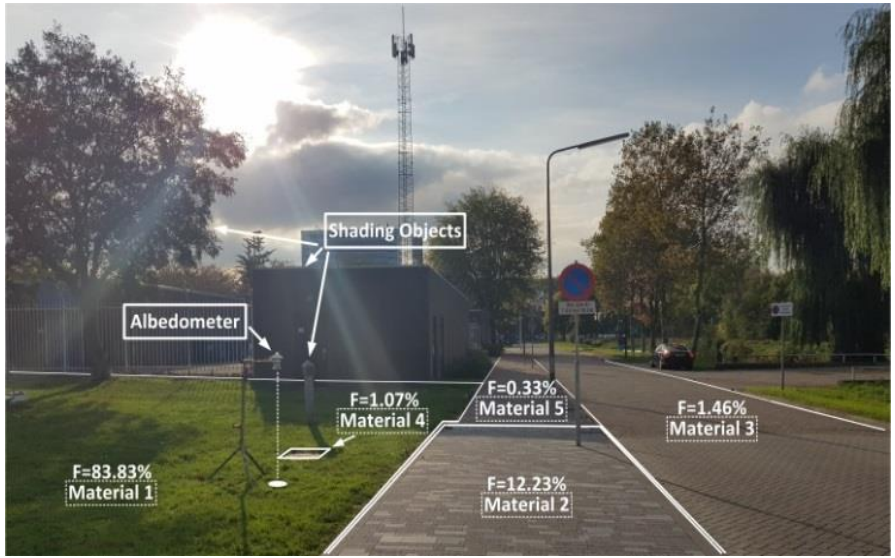
$$\alpha \leq R$$

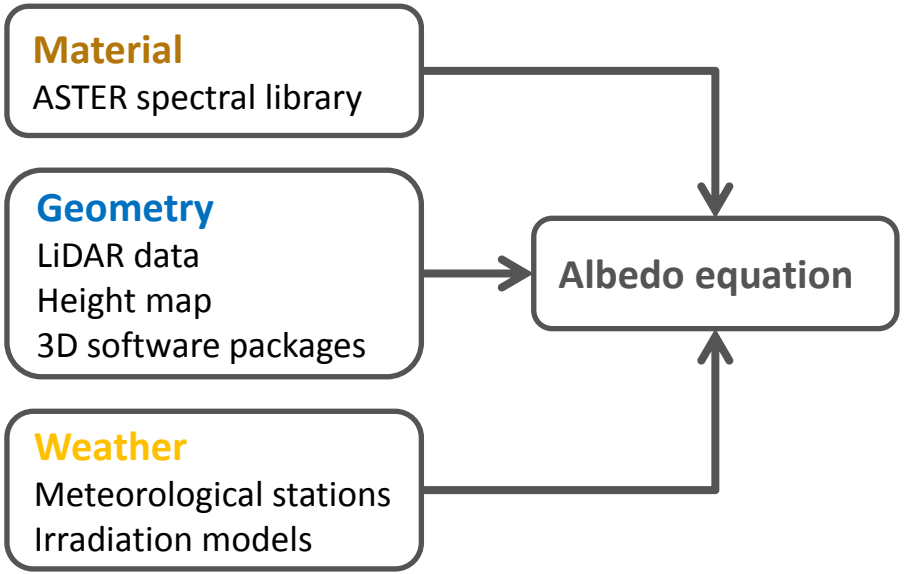
H. Ziar, et al., *Applied Energy*, **255**, (2019)

Put the model into test

- Experiment

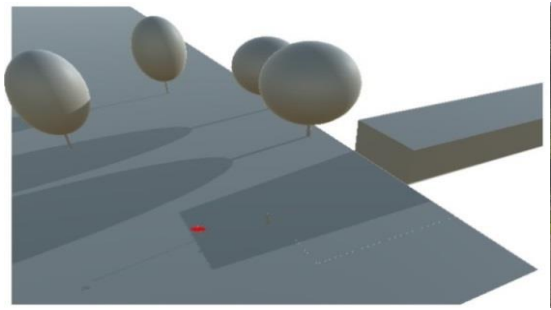


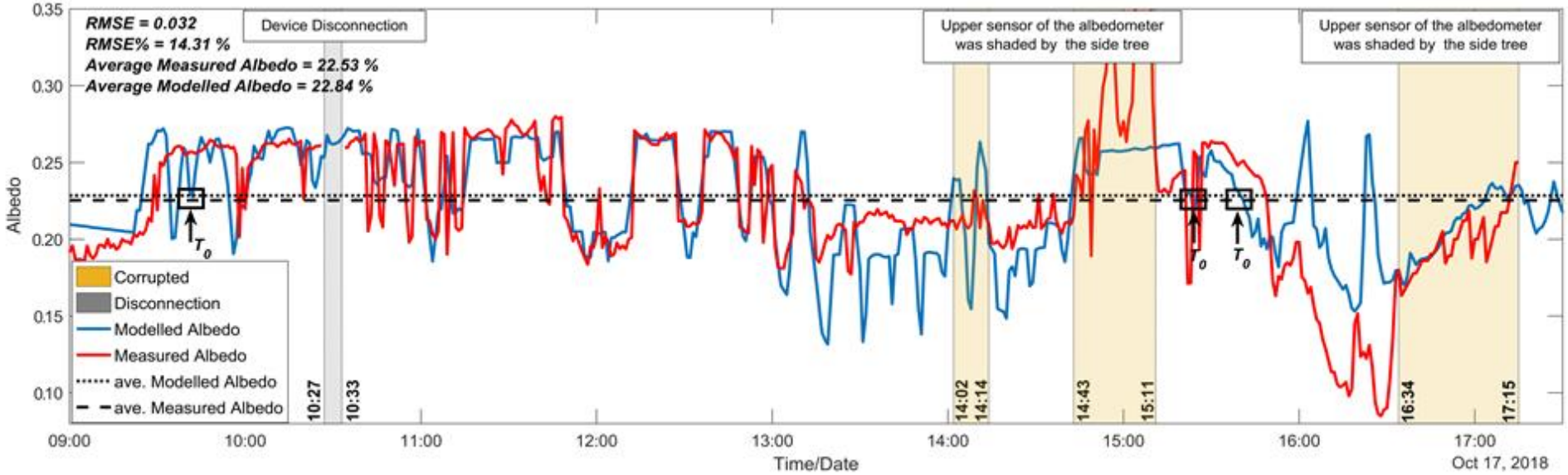
- Simulation



Albedo model validation

- Low RMSEs of 0.012 and 0.032 good agreement between prediction and measurement.





H. Ziar, et al., *Applied Energy*, **255**, (2019)

Applications of the proposed albedo equation

- Remote Sensing
- Local and Global Warming
- Geology and Agriculture
- Energy and Photovoltaics
- Computer Graphics
- Conceptual Application

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Applications of the proposed albedo model

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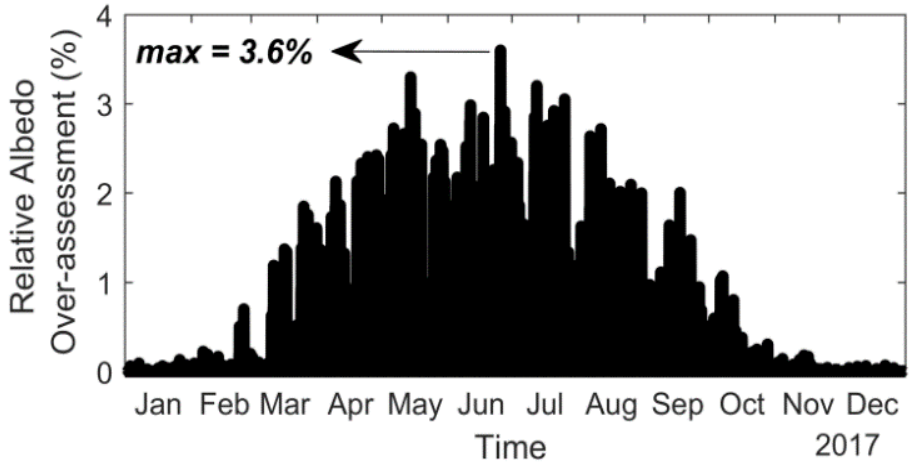
avoiding energy yield over-estimation



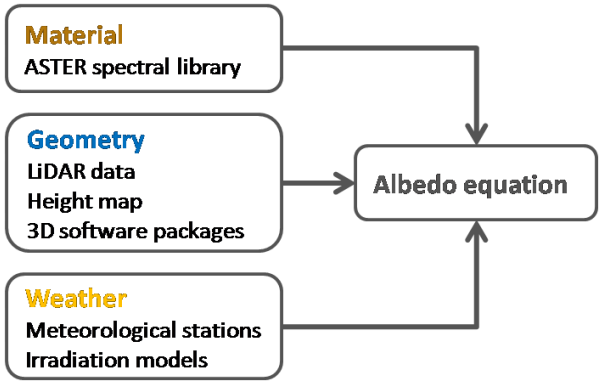
- Overestimation of (*33 kWh/m2/year × average albedo before installation*) in DC-yield prediction.

Summary of results

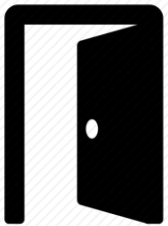
- A coherent model to cluster all the parameters which affect albedo in one equation.

$$\alpha = \sum_{i=1}^{i=N} R_i \left(C_i F_{S \to A_{i1}} + \frac{1}{H+1} \left(C_i' F_{S \to A_{i1}} + F_{S \to A_{i2}} \right) \right)$$

- The model can calculate the albedo without the need for in-field measurements.



- The model can be deployed in many fields of research concerned with urban and solar energy.



Thank you for your attention

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