Further Relevant Meteorological Parameters

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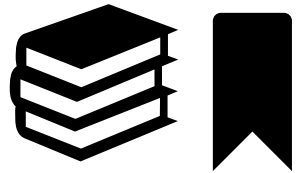
Overview of the new chapter and presentation

- Many meteo. parameters required for solar energy besides broadband irradiance
  - Wind
  - Ambient temperature and relative humidity
  - Atm. Pressure
  - Precipitation
  - Aerosols & water vapor
  - **Spectral irradiance**
  - UV irradiance
  - **Soiling**
  - Circumsolar radiation
  - Beam attenuation between heliostats & receivers of tower plants
  - **Surface albedo**

-Definitions
-Effects on solar energy
-Measurement options
-Modelled data sources
-References



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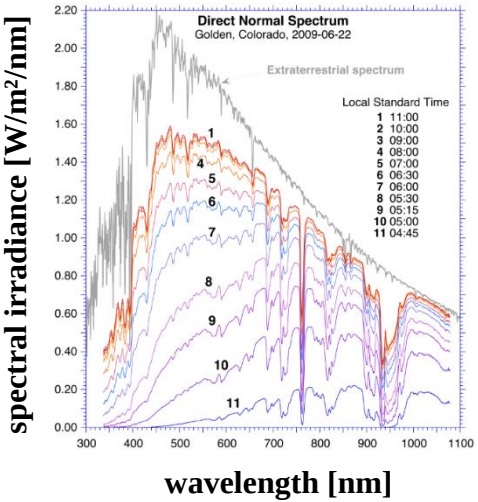
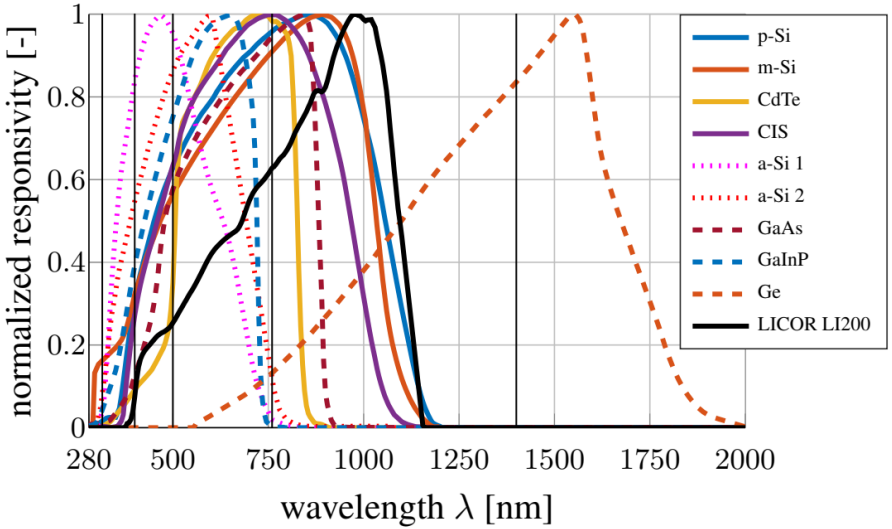
Spectral Irradiance

- Solar irradiance spectra vary strongly with solar position & atmospheric conditions
- Some solar energy systems and radiometers only use part of the solar spectrum
- Yield estimations might be wrong if assumptions on spectrum are wrong
  - Even for cSi yearly yield estimations -5% to +2% error can occur





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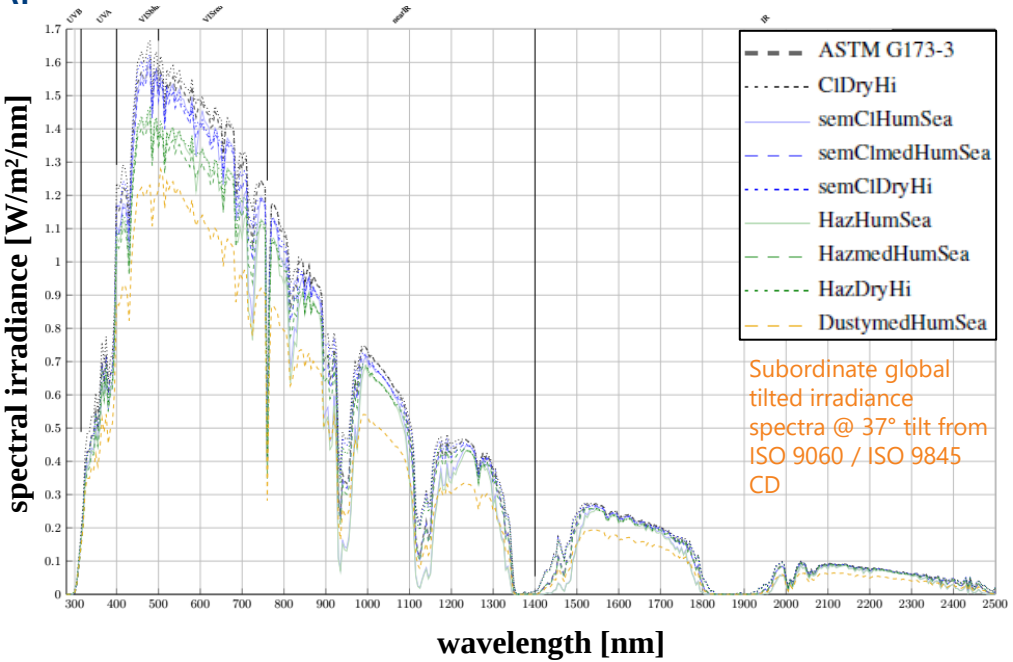
Spectral Irradiance

- Spectroradiometers are expensive, require laboratory calibration, and some require significant maintenance effort
  - For wide spectral ranges, several detectors are required (Si sensors not usable beyond ~1100 nm)
  - Limited to research stations
- Options that combine measurements with modelling could be a solution


CCD array spectroradiometer system WISER at CIEMAT's PSA (global, direct, 300-1700 nm)

Spectral Irradiance

- Modelling options:
  - SMARTS, FARMS, libRadtran, …
- Data: TMY Spec, NSRDB, CM SAF
- Standards
  - ASTM G173-03 (ASTM 2020a)
  - ASTM G197-14
  - IEC 60904-3
  - ISO 9845, ISO 9060
  - CIE 241:2020
- Further section on UV



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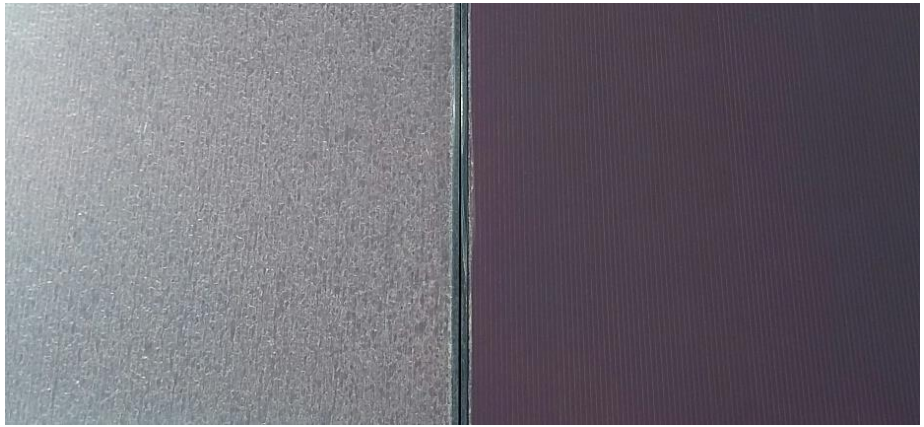
Soiling

- Soiling ratio = efficiency of actual system / efficiency of clean system
- Strongly relevant parameter for all solar energy technologies
  - Even in Germany, observed soiling ratios are below 50% and average loss ≈3%
  - Cleaning schedule
  - Separate the soiling issue from other technical problems

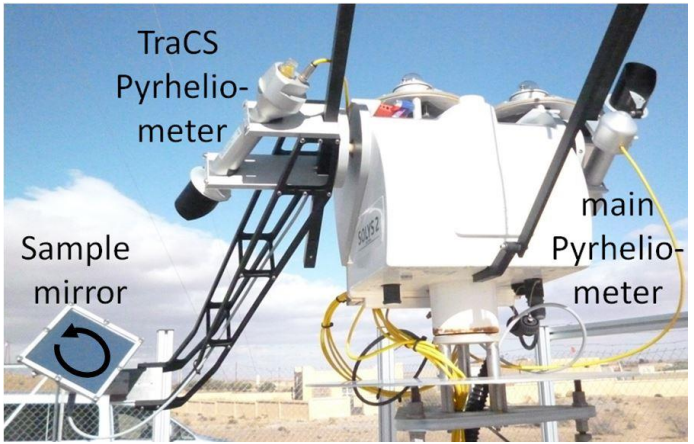


PV Soiling Measurement

- Various measurement options:
  - Compare reference cells or modules
    - ➢Cleaning of reference needed
    - ➢Inhomogeneous soiling is problematic for I_{sc}-based measurements
  - Soiling sensors
    - ➢Active light source
    - ➢Microscope for visualization of particles
    - ➢Image-based techniques
  - Measure efficiency change due to cleaning (can be difficult…)

Soiling Measurement for CSP

- Soiling effect is mostly scattering
  - CSP ~10 times more affected than PV because of small CSP acceptance angles
- Absorbers, envelope tubes of absorbers and other entrance windows of receivers are affected—not just reflectors or concentrators
- Measurement options:
  - TraCS
  - AVUS
  - handheld reflectometers (time consuming)

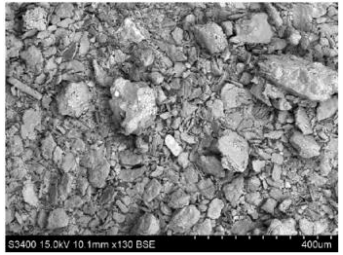


Soiling Modelling

aerosol concentration

precipitation

(3D) wind, humidity, temperature, dew



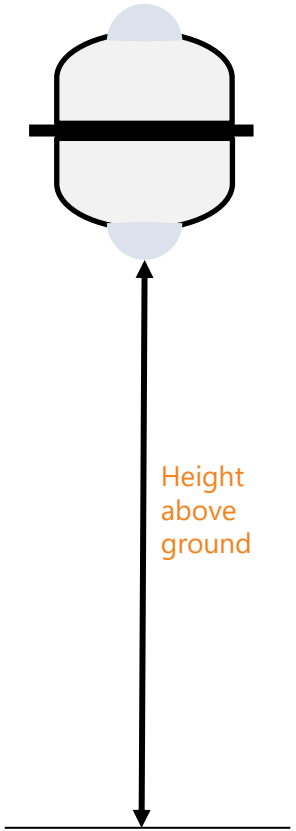
soil properties and solar system surface properties

soiling model

change of soiling ratio

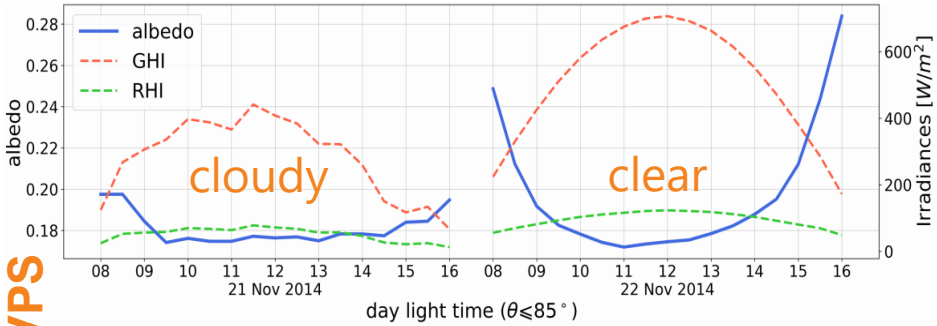
Albedo

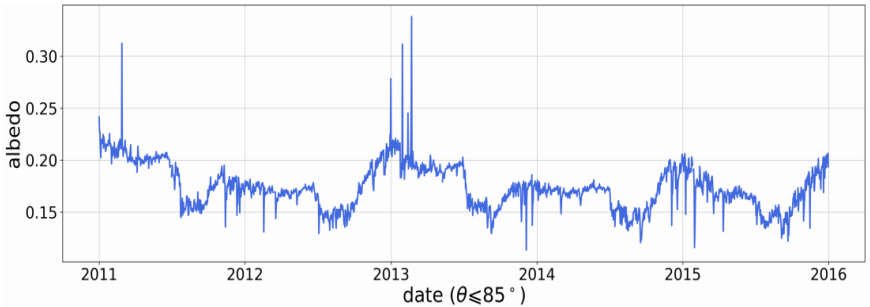
- Albedo = RHI/GHI
  - ➢Reflected horizontal irradiance (RHI)
  - ➢Global HI
- Relevant in particular for all non-concentrating tilted systems (contribution from ground)
  - Especially bifacial PV: Backside POA can be modelled using albedo, direct & diffuse irradiance (raytracing, sky view factor)
- Modelling of surface irradiance requires albedo
- Measurement setup with 2 pyranometers:
  - for PV: height 1.5 – 2 m (ISO TR 9901, IEC 61724-1)
  - for comparison to spaceborne observations: >10m



Albedo

- Albedo is highly variable (spatially, temporally)
- RHI = BSA·DIR + WSA·DHI
  - DIR and DHI denote the direct and diffuse horizontal irradiances
  - black-sky albedo (BSA): directional hemispherical reflectance for direct irradiance
  - white-sky albedo (WSA): reflectance under isotropic diffuse illumination
- Data sources: MODIS, ERA5, Mines ParisTech, CM SAF, …





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Thank you!

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