Albedo from satellite and ground-based observations

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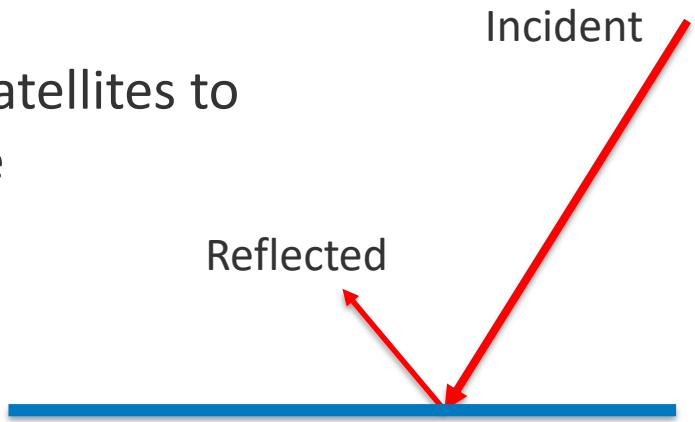
Albedo

- Albedo of a surface is the fraction of the incident sunlight that the surface reflects
- Ground-based albedos are measured with sky-facing and ground-facing pyranometers
- Satellite-based albedos use sensors on satellites to measure the ground-reflected irradiance

Albedo = Reflected ÷ Incident

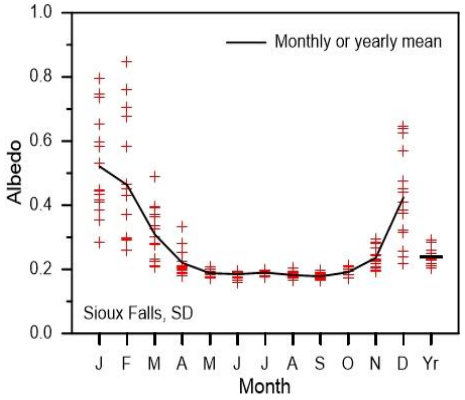


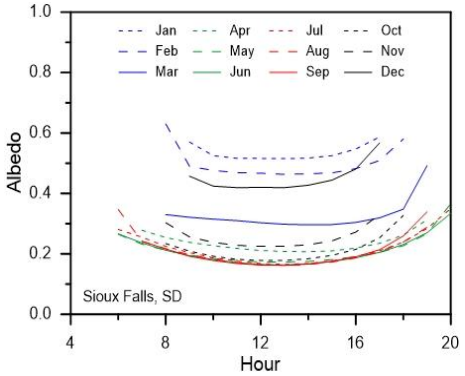
Ground-Based Albedos

- The U.S. DOE initiated work with NREL to provide albedo data and statistics in order to facilitate better performance estimates and to reduce their risk.
- SURFRAD and AmeriFlux network data
- Data contributed by the PV industry

Data Products

- Time-series data at (1) the original temporal resolution (from 30 seconds to 30 minutes) and (2) reformatted to hourly data
- Albedo statistics – monthly and yearly means, medians, minimums, maximums, and standard deviations
- User's Guide – Describes available data sets, site information, and provides graphs of seasonal and diurnal variations
- Data products are available from: https://datahub.duramat.org/project/about/albedo-study





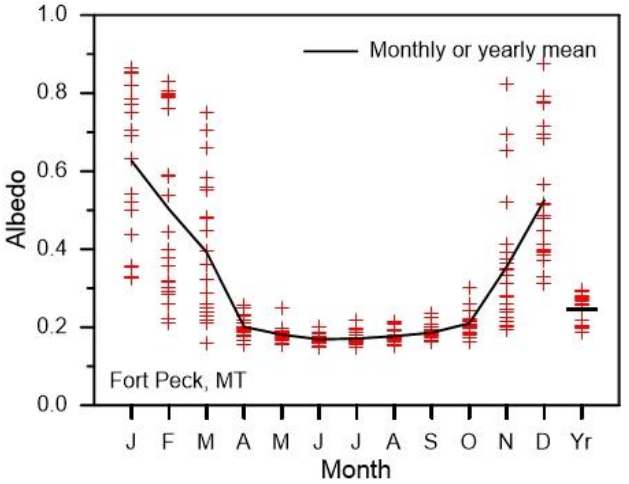
Data Elements

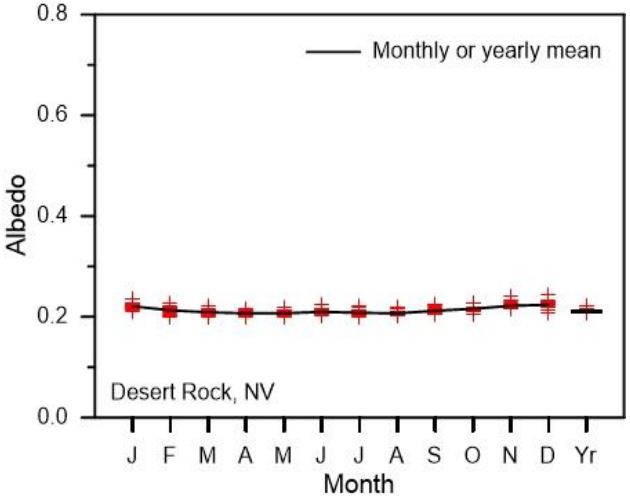
- Global Horizontal Irradiance (GHI) and Ground-Reflected Irradiance (GRI). GRI may be otherwise referred to as upwelling, outgoing, or reflected horizontal irradiance.
- Direct normal irradiance, diffuse horizontal irradiance, dry bulb temperature, relative humidity, wind speed, wind direction, atmospheric pressure, and precipitation.
- Quality assessment flags assigned to data to indicate if within reasonable limits.

SURFRAD

Surface Radiation budget (SURFRAD) network

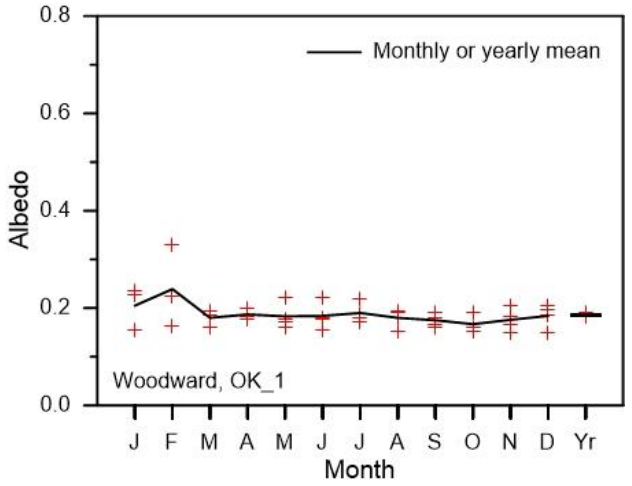
- Operated by National Oceanic and Atmospheric Administration (NOAA)
- High quality measurements to support climate research, weather forecasting, satellite and education communities
- 7 stations, 15 to 24 years of data

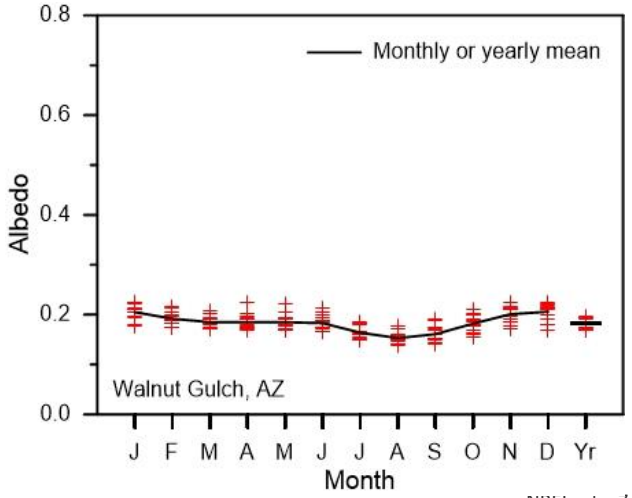




AmeriFlux

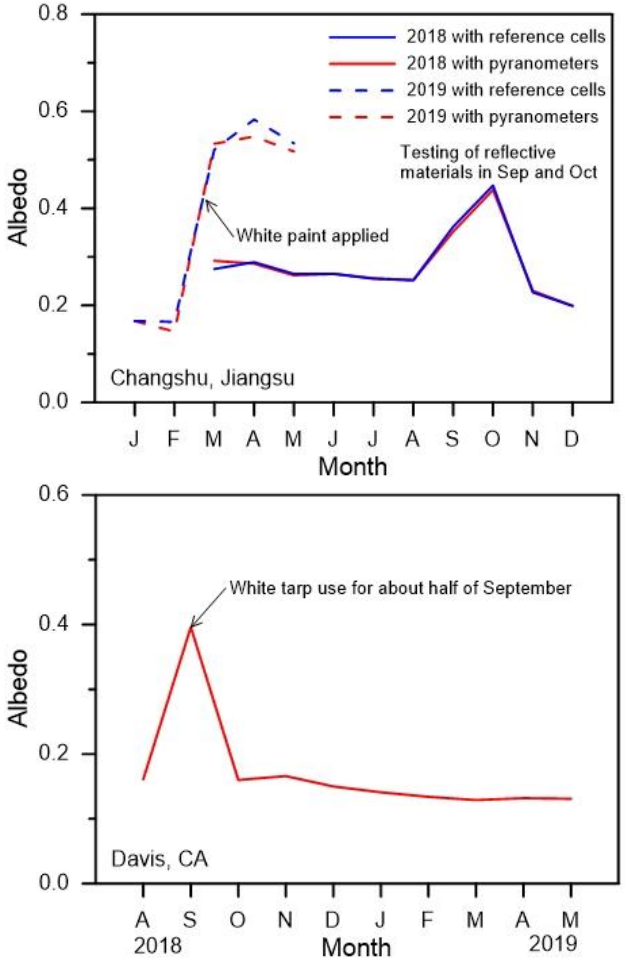
- Network managed by the Lawrence Berkeley National Laboratory
- Stations managed by individual scientists in North, Central, and South America
- Purpose is measuring ecosystem CO2, water, and energy fluxes
- We used a subset of 28 stations (grasslands, deserts, low brush or crops)
- From 1 to 15 years of data, information on equipment and maintenance varies by station



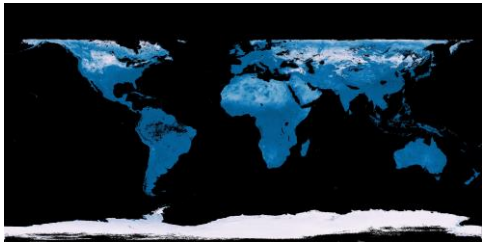


PV Industry

- Changshu, Jiangsu, China concrete surface data contributed by Canadian Solar, Inc (Jean-Nicolas Jaubert, Baohua He)
- Davis, CA gray gravel surface data contributed by SunPower Corp (Ben Bourne, Fabrizio, Adam Hoffman)



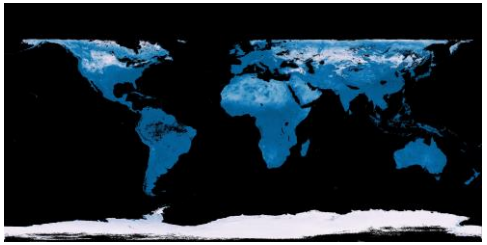
Satellite Albedos



- Albedo is an essential parameter for determining the earth's energy balance and climate change
- 28 public-domain gridded albedo or reflectance databases per Gueymard et al., 2019[1]
- Gueymard compared National Solar Radiation Database (NSRDB) to other satellite albedo data bases
  - Using 0.8669 for snowy pixels overestimated winter albedos
  - Seasonal variability was out of phase

1. Chris Gueymard et al. Surface albedo and reflectance: Review of definitions, angular and spectral effects, and intercomparison of major data sources in support of advanced solar irradiance modeling over the Americas. Solar Energy 182 (2019) pp 194-212.

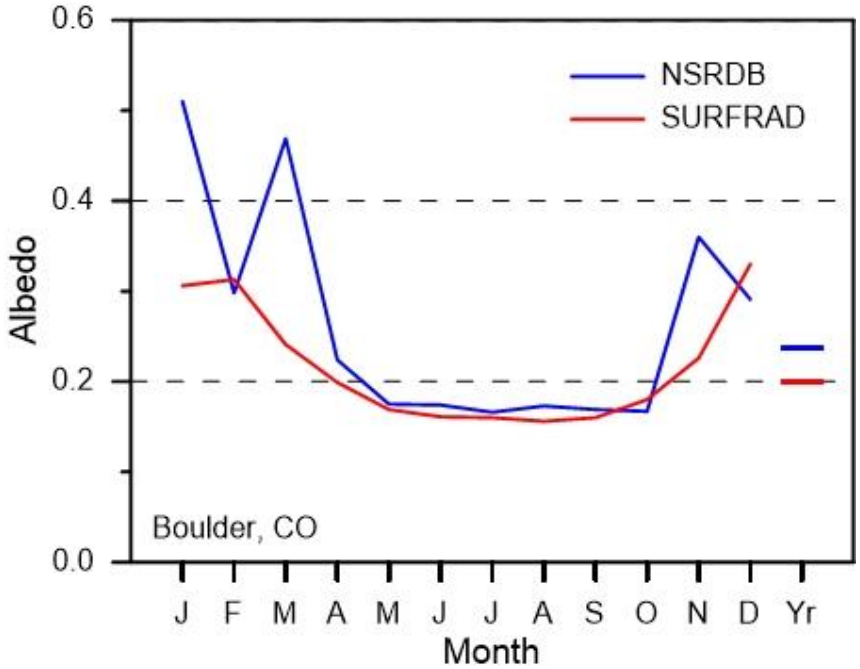
NSRDB Albedos



- Moderate Resolution Imaging Spectroradiometer (MODIS) 30 arc-second data processed to match NSRDB 4-km grid
- Incorporates a snow-day product from NOAA, albedo set to 0.8669 when snow present
- Uses daily albedo values to address changing snow cover rather than the MODIS 8-day temporal resolution

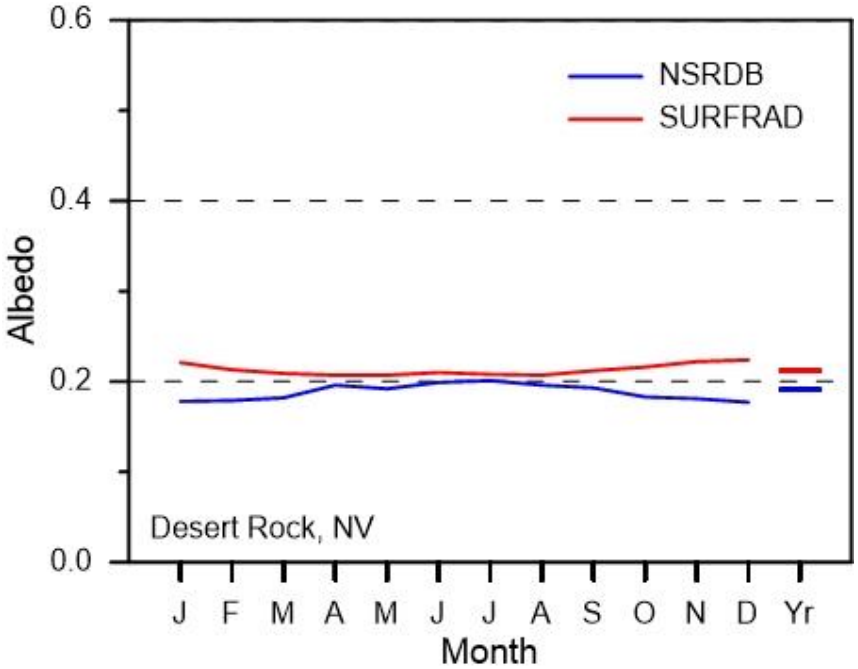
NSRDB versus SURFRAD

- Boulder, CO – NSRDB overestimates albedo for months with snow, good agreement for other months



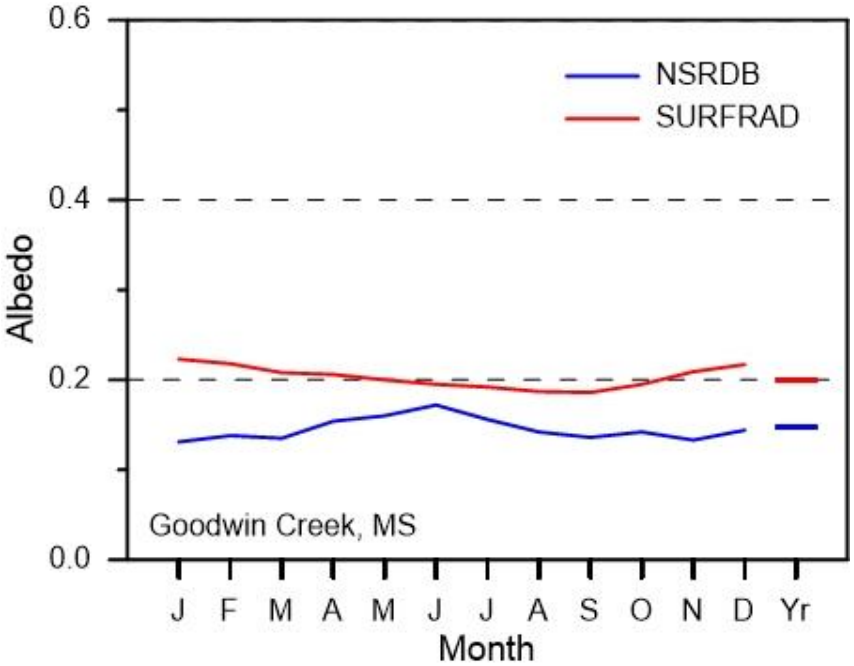
NSRDB versus SURFRAD

- Desert Rock, NV – NSRDB albedo compares well with SURFRAD, but seasonal variability is out of phase



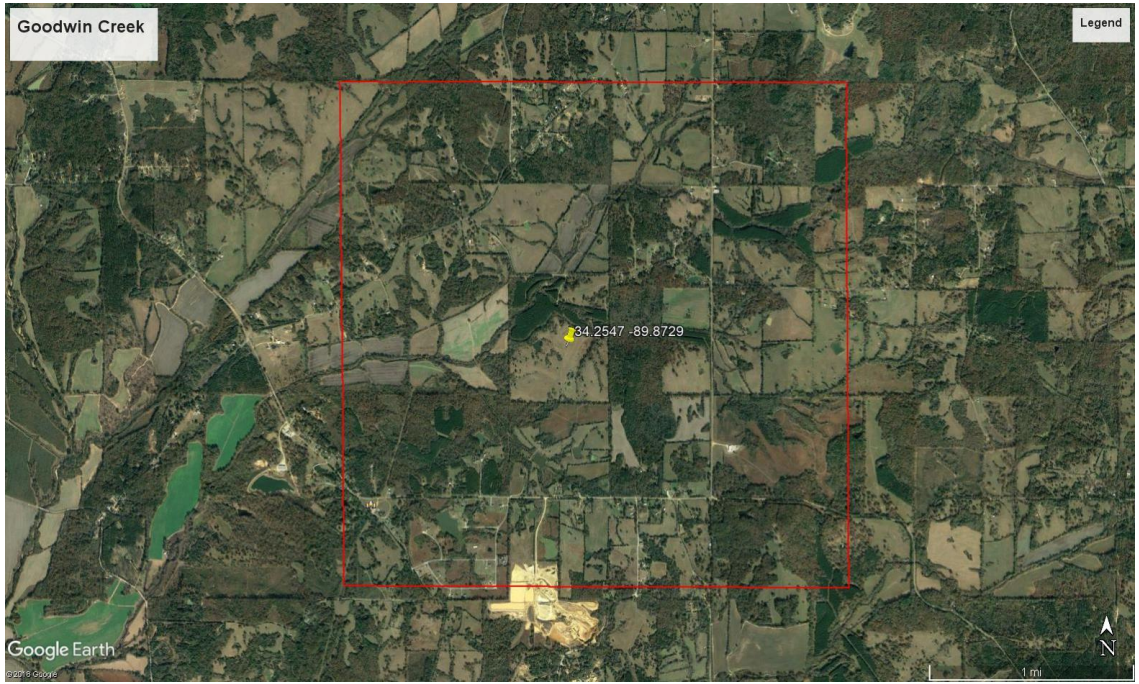
NSRDB versus SURFRAD

- Goodwin Creek, MS – NSRDB albedos less than measured
- Ground surface seen by satellite may not be representative of that measured by SURFRAD



Google Earth Image

- NSRDB 4 km cell outlined in red, Goodwin Creek station located at yellow pin.
- NSRDB cell generally darker than SURFRAD station location, resulting in under-estimating albedo at station location.



Summary

- Measured albedo data and summaries for 37 locations are available from NREL's DuraMat website
  - Monthly and annual means and year-to-year variability for various locations and ground surfaces
- Satellite albedos can be close to measured values, but snow may be problematic for the NSRDB and the ground viewed within the satellite cell should be checked for similarity with the project site
- More albedo data contributions by PV industry would be useful to represent as-built scenarios

Thank you

www.nrel.gov

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