



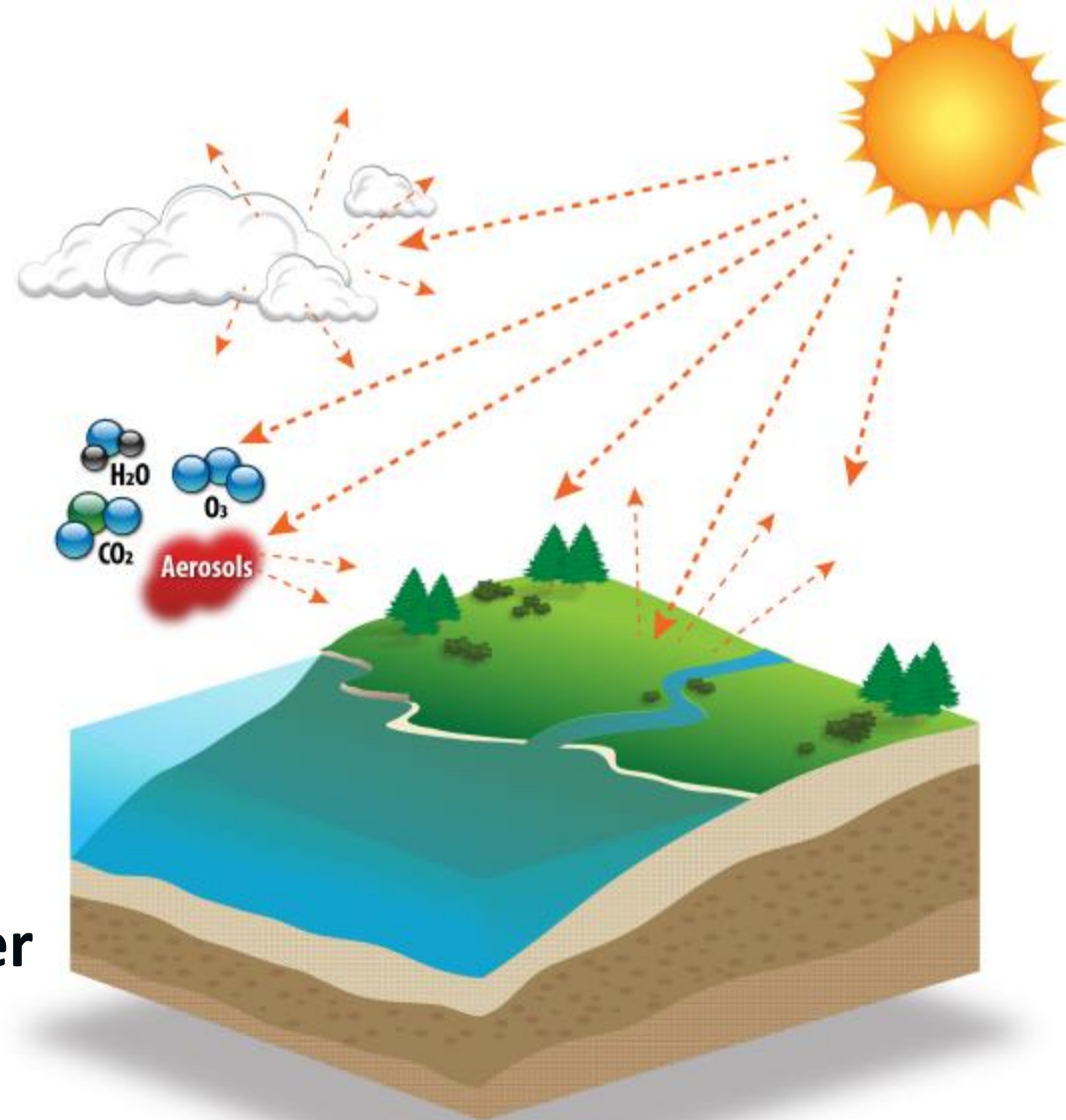
Bridging the Radiative Transfer Models for Meteorology and Solar Energy Applications

Yu Xie and Manajit Sengupta

AGU Fall Meeting, December 12, 2017

Radiative Transfer Model

- Considers interactions with atmospheric constituents and land surface.
- Important in changes of temperature, wind and precipitation.
- Also important in solar energy industry: policy decisions, design of solar energy system, and power systems integration.



Solar energy has unique requirements on models

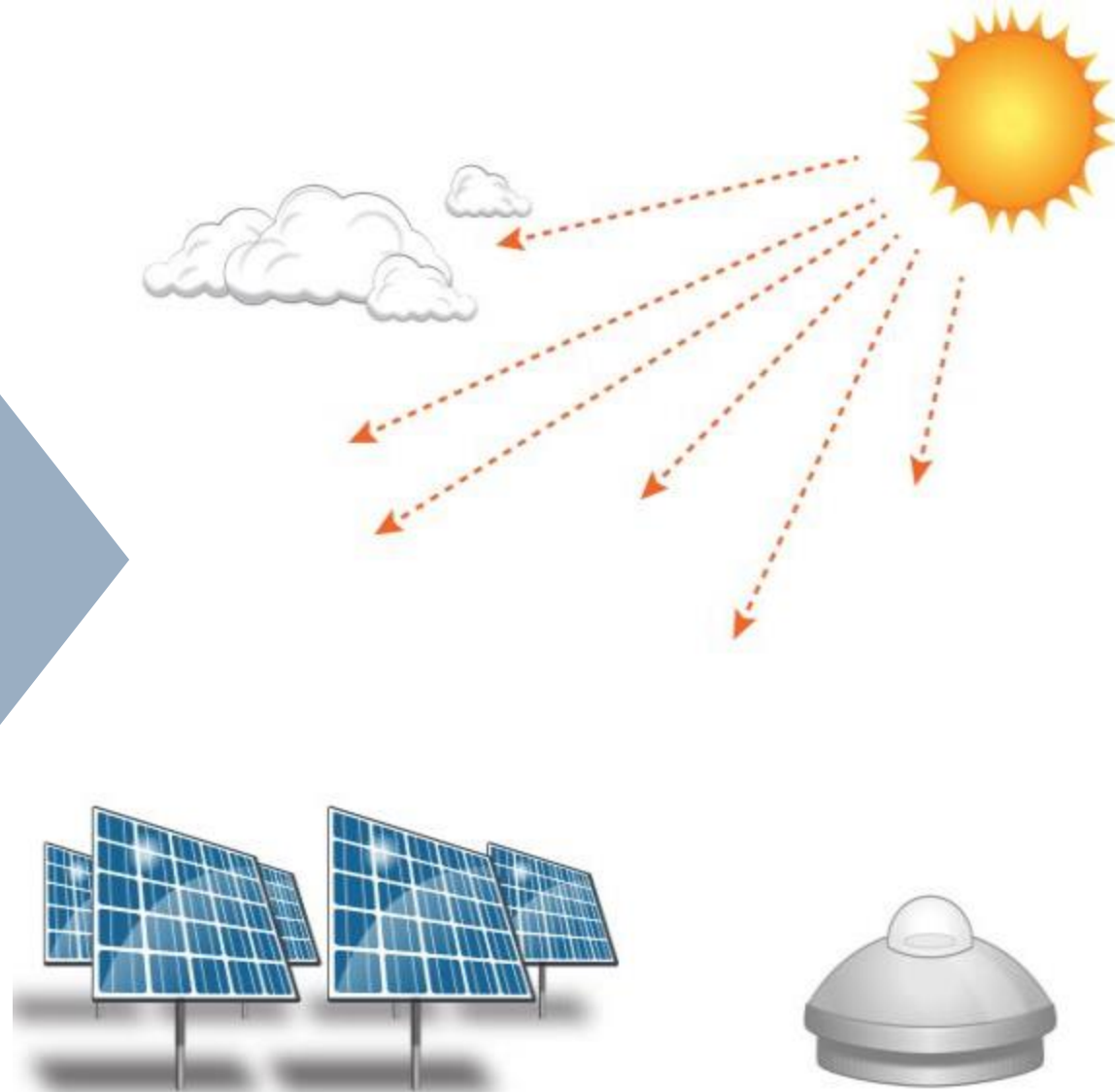
Inclined Surfaces

Fast Computation

Bifacial PV

Inhomogeneous surfaces

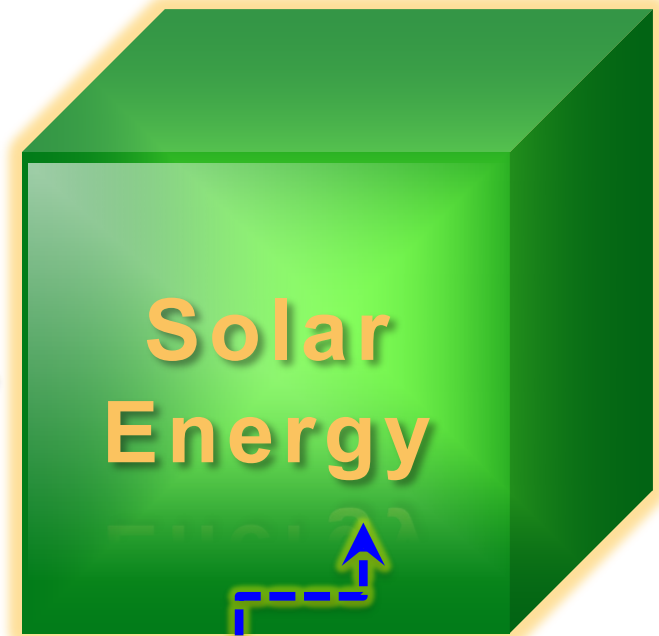
Spectral radiation



Solar energy models are empirical and time efficient



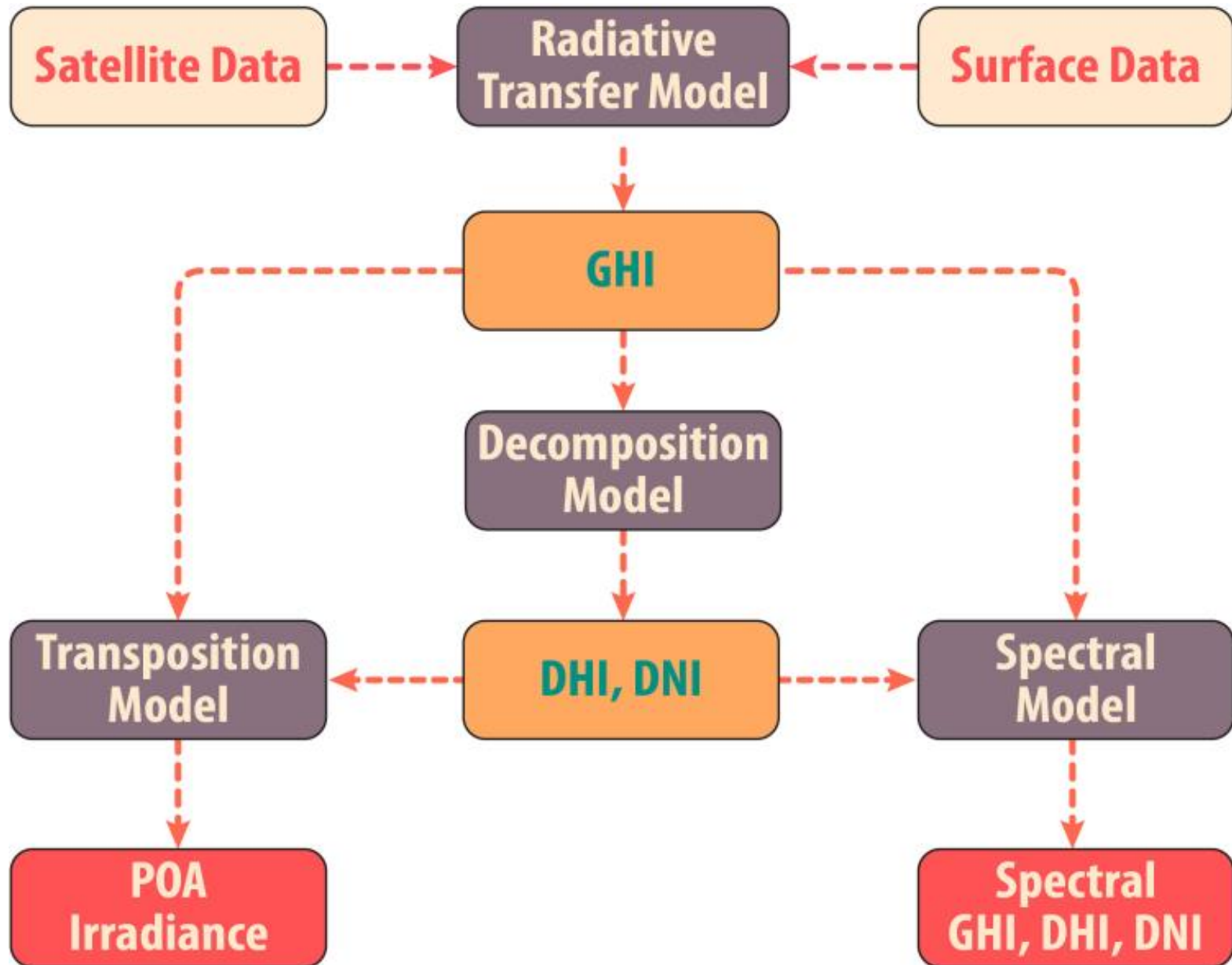
- Solving the Radiative transfer equation for clear and cloudy conditions
- Time consuming



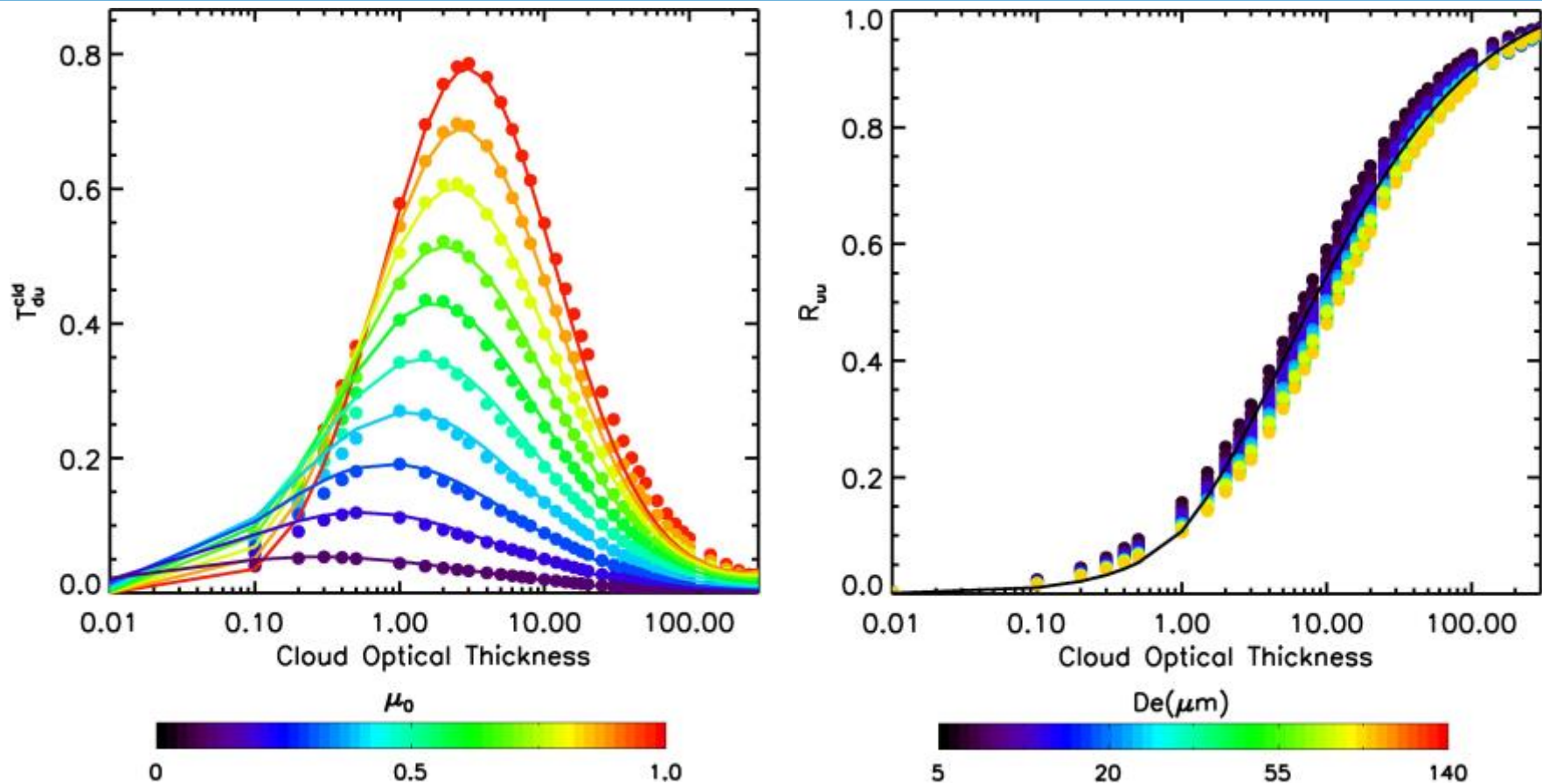
- Regression and parameterization
- Most for clear sky
- Time efficient

The Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS) computes clear-sky solar irradiances in 2002 wavelengths using <0.1 second.

Solar energy models have uncertainties

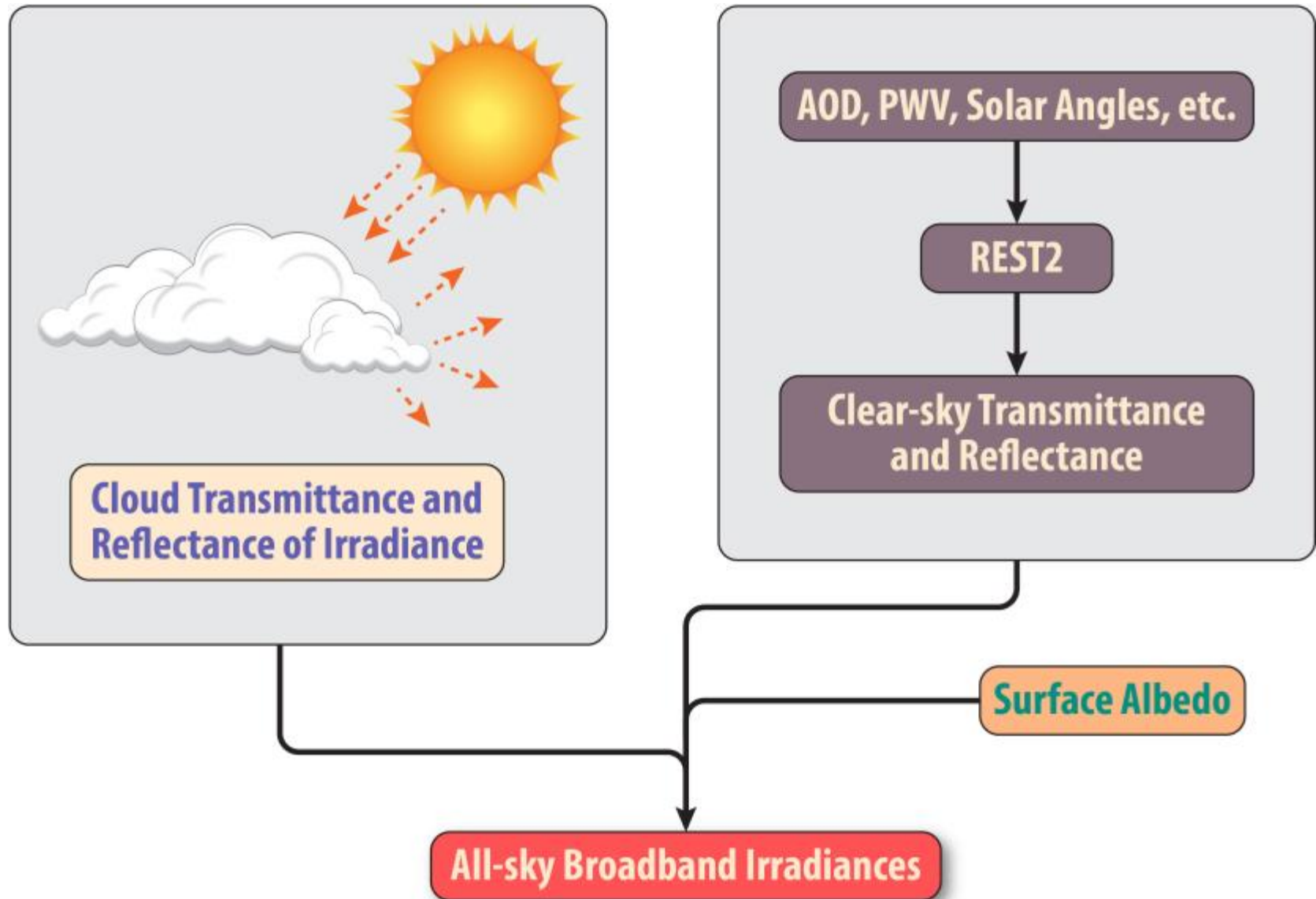


Parameterization of cloud transmittance and reflectance



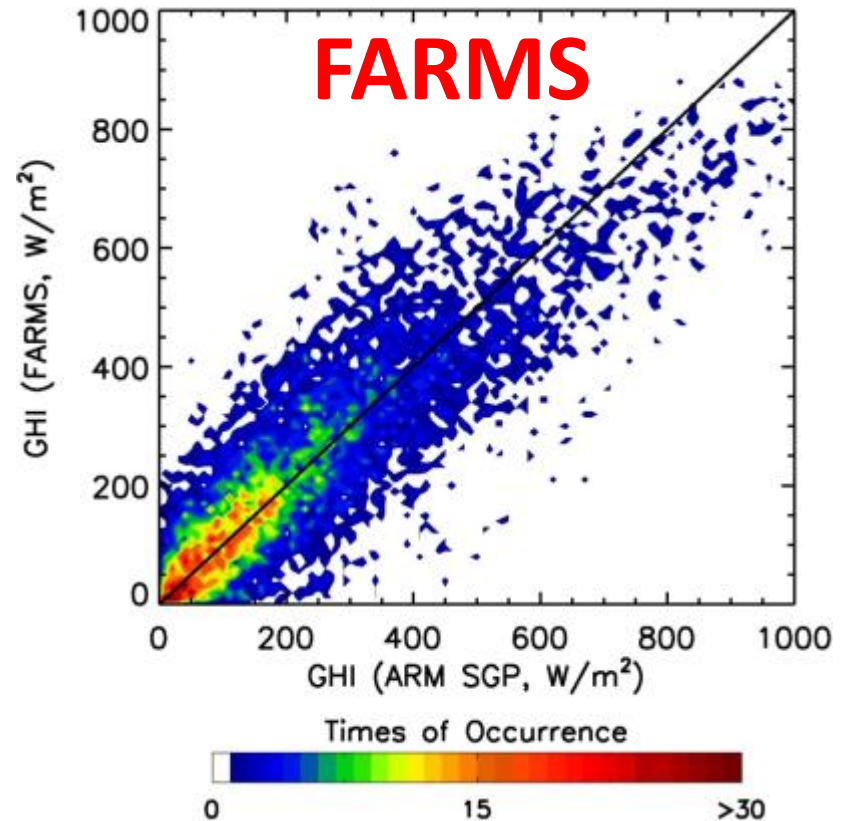
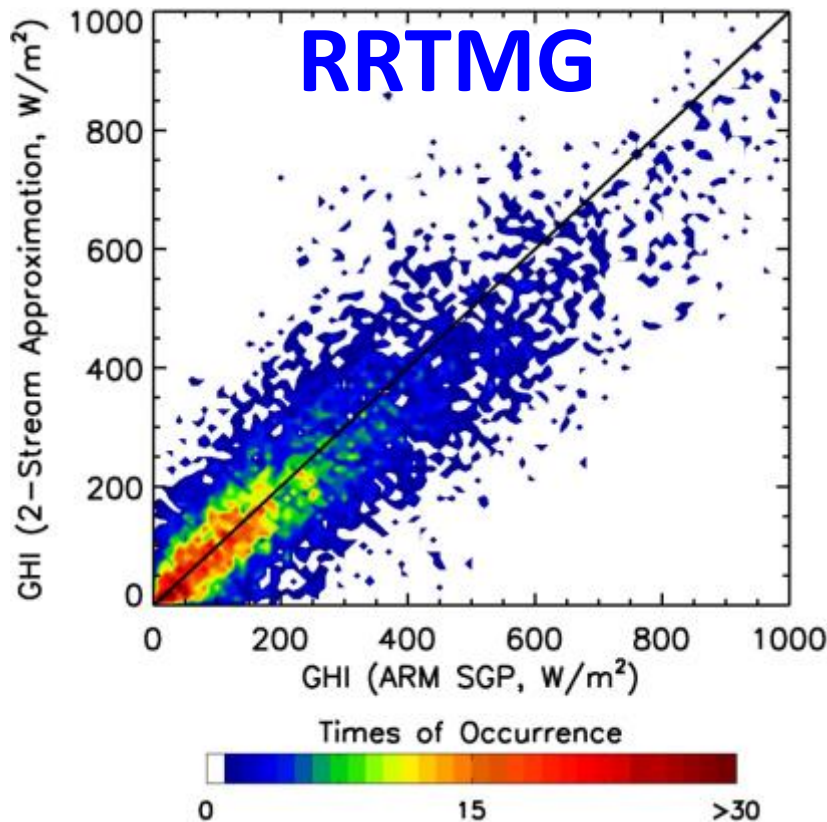
- Cloud transmittances are parameterized as exponential functions of cloud optical thickness and solar zenith angles.
- Cloud reflectances are parameterized using simple equations of cloud optical thickness.

Fast All-sky Radiation Model for Solar applications (FARMS)



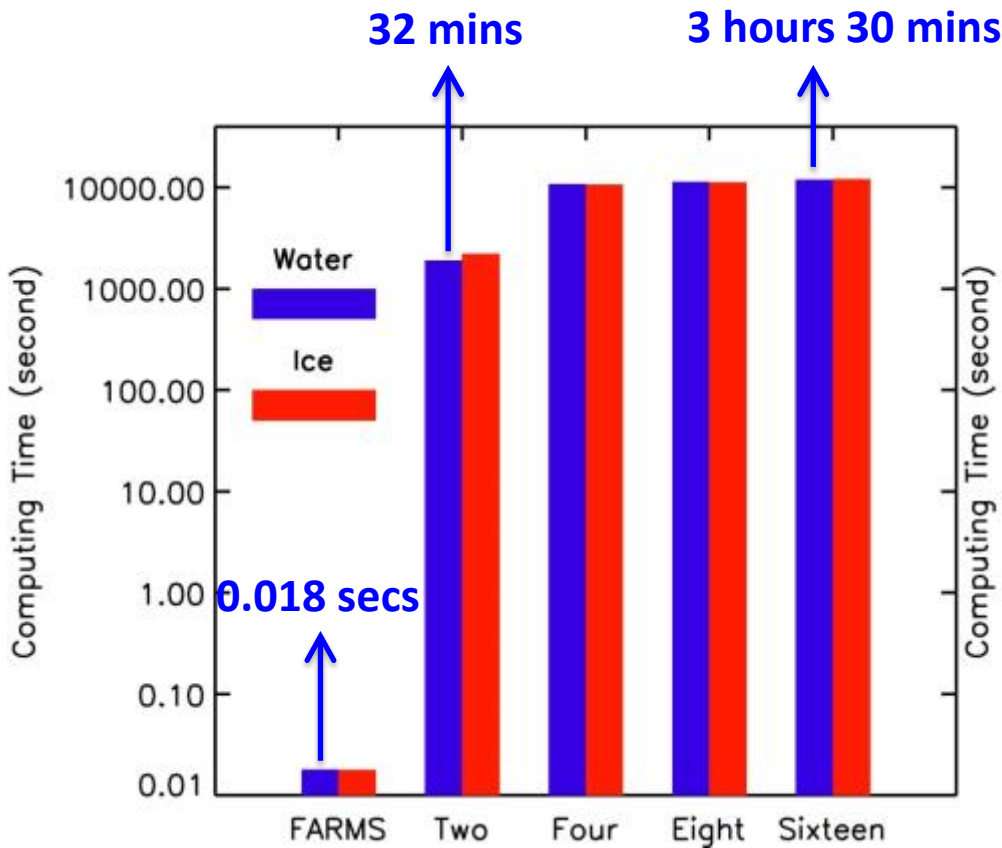
Xie et al., *Solar Energy* (2016)

FARMS is as accurate as RRTMG

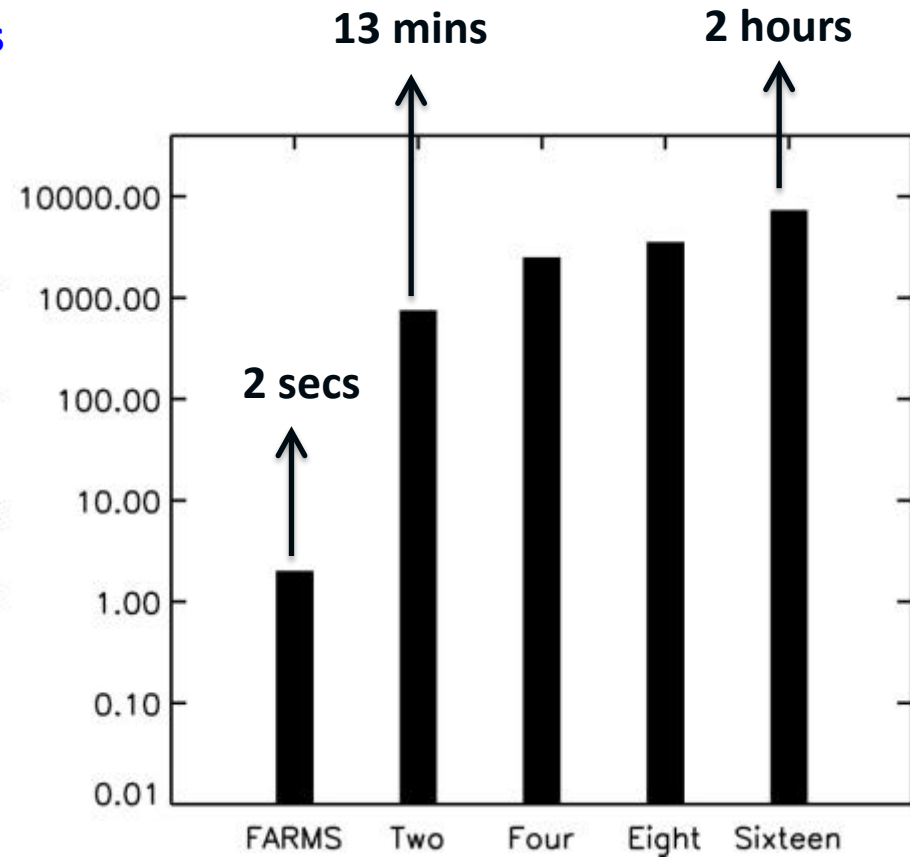


GOES satellite data is collocated to ARM SGP site. The satellite-based retrievals of cloud properties are used as inputs to two stream and FARMS. A total number of 9669 scenarios associated with cloudy-sky are selected during 2009-2012.

FARMS is much more time efficient

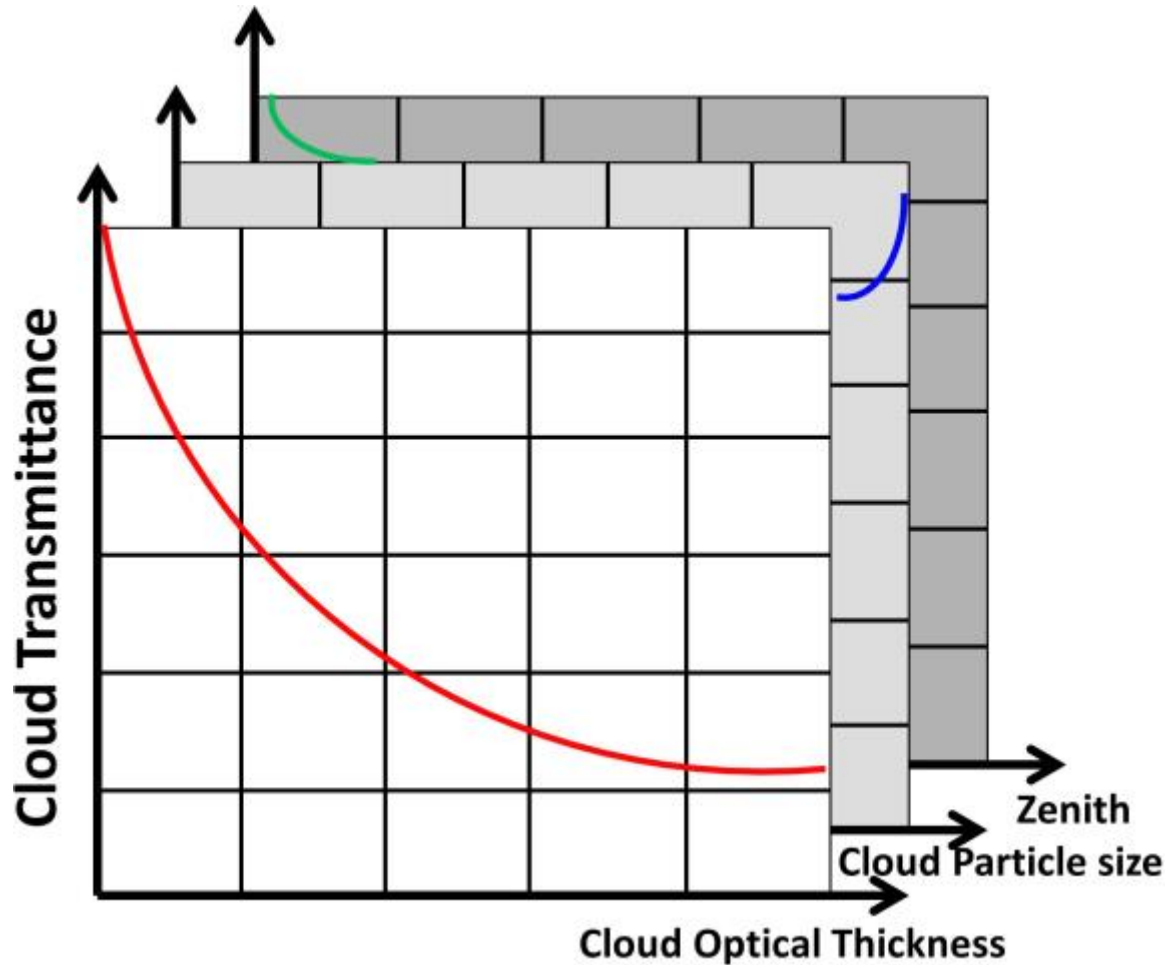


Computation of cloud T for 39 cloud optical thicknesses, 28 particle sizes, and 50 solar zenith angles.



Computation of solar radiation for 9669 scenarios of cloudy sky conditions over ARM SGP.

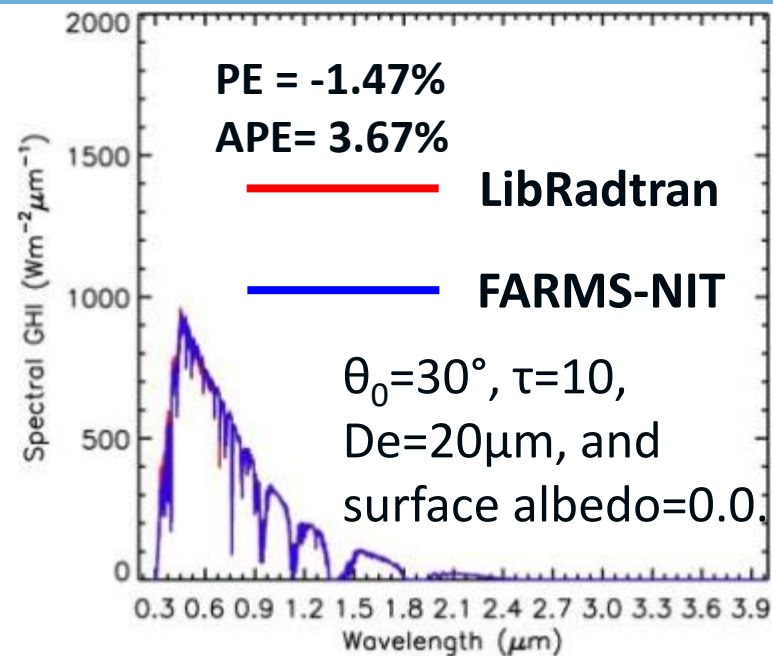
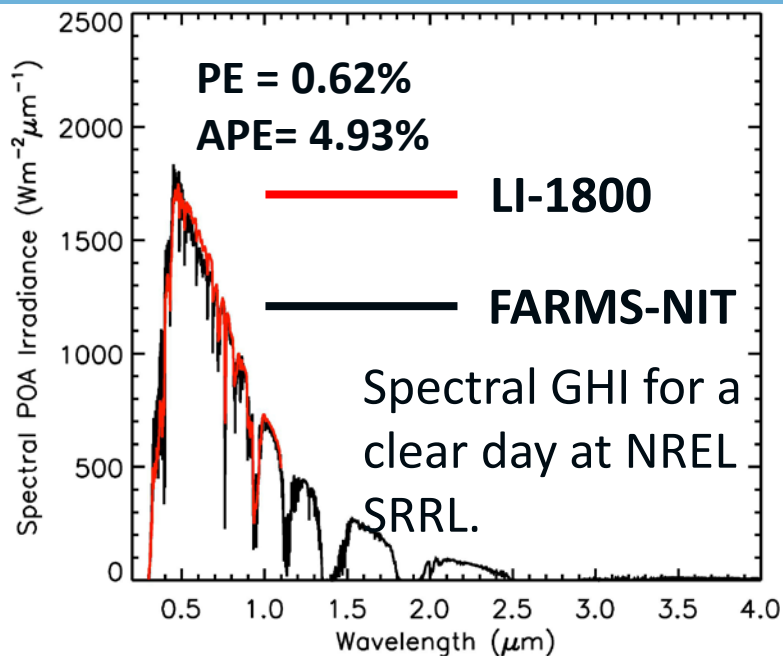
Narrowband Irradiances on Tilted surfaces (FARMS-NIT)



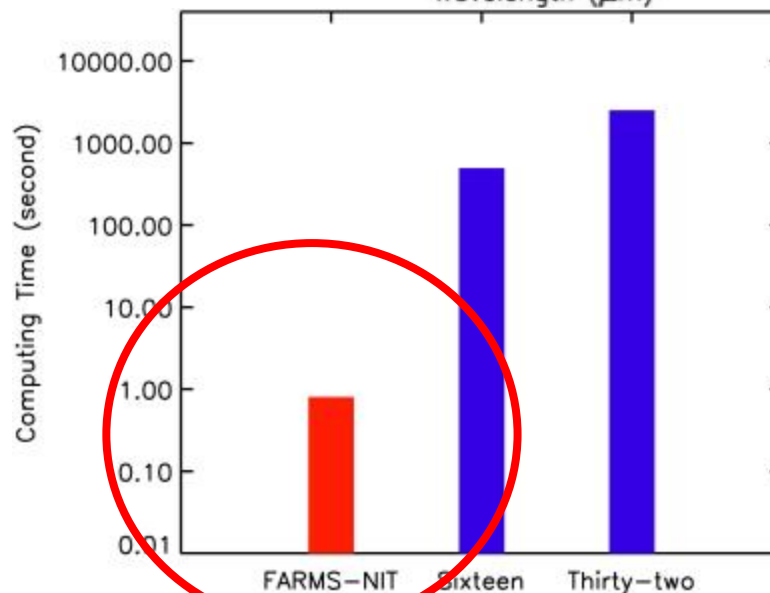
A lookup table of cloud transmittance was computed.

POA irradiance is computed by integrating radiances over inclined surfaces.

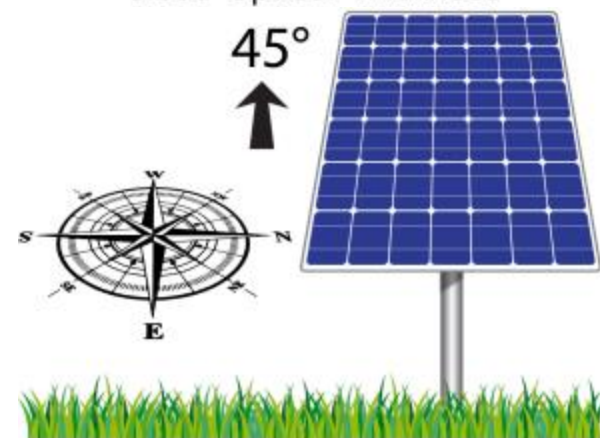
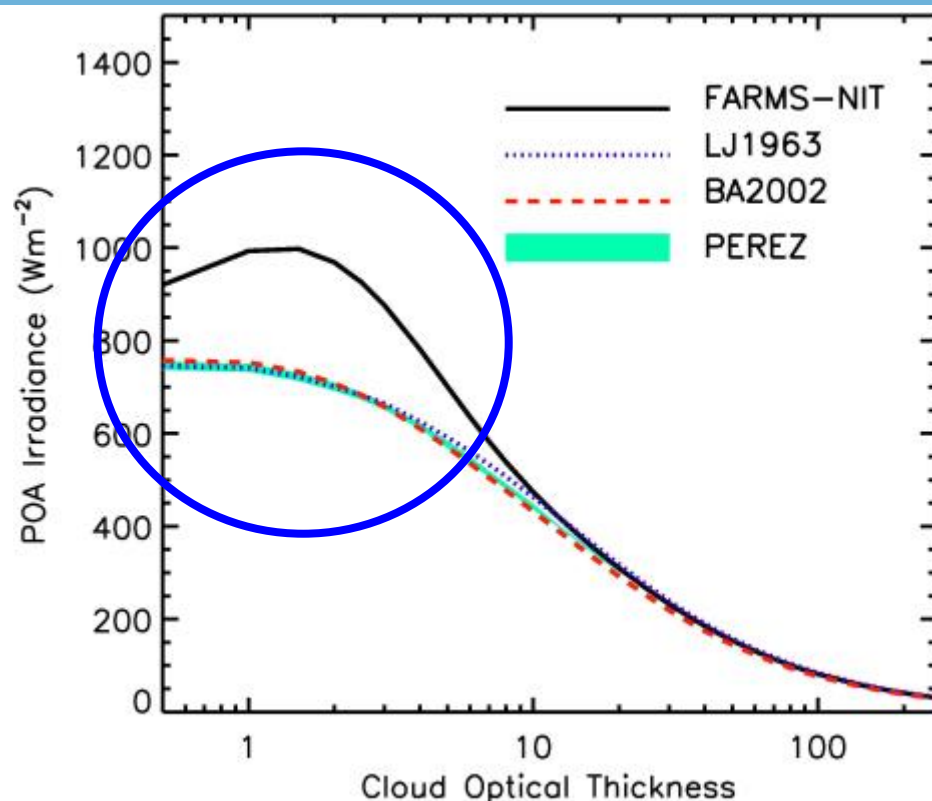
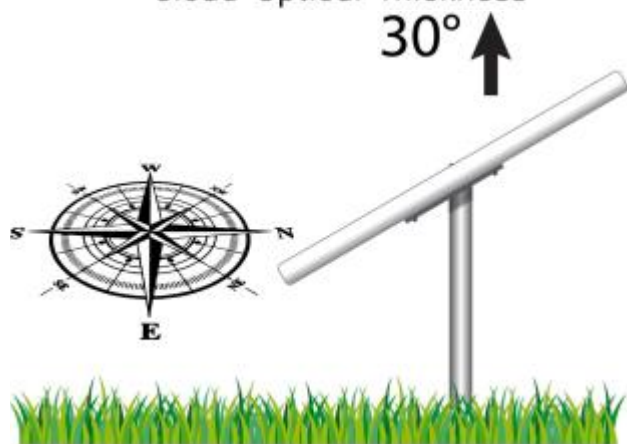
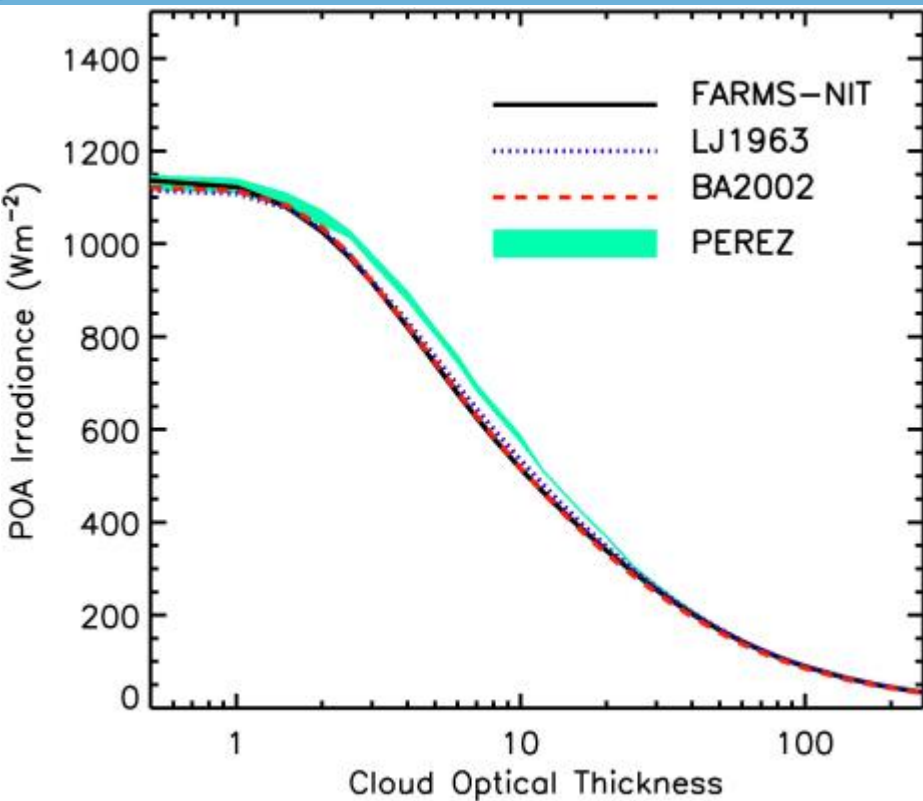
Bias of FARMS-NIT is within 5%



FARMS-NIT: 0.8 second.
LibRadtran (16 stream):
492 seconds.
LibRadtran (32 stream):
2493 seconds.



FARMS-NIT is more accurate than transposition models



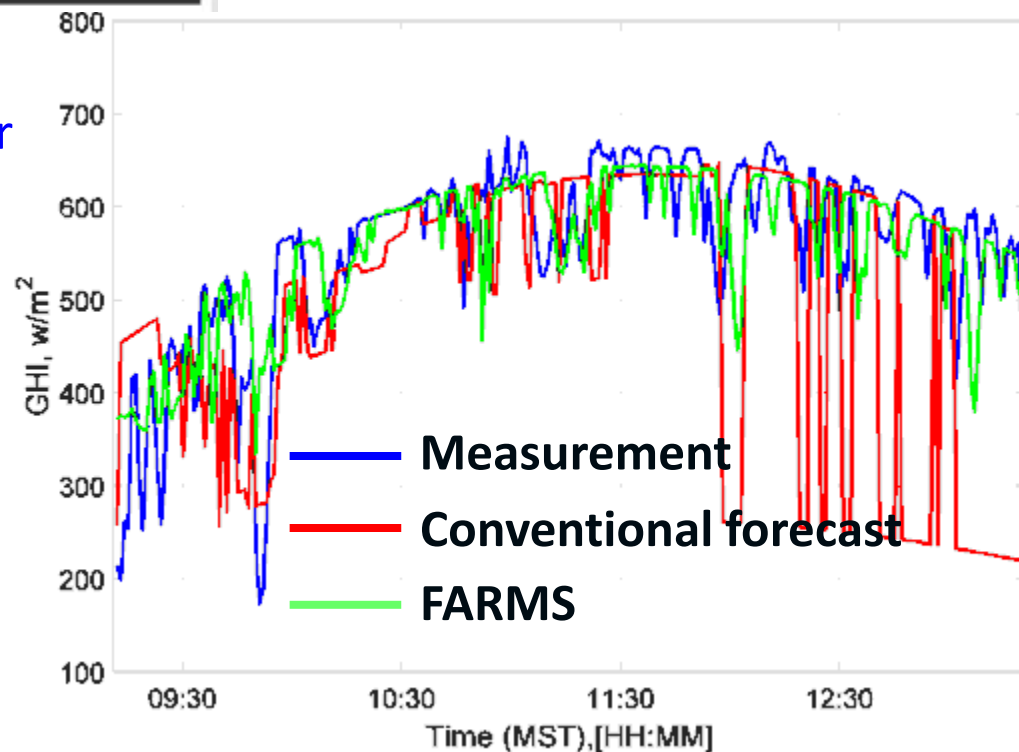
Applications and Future Work

The screenshot shows the RAL (Research Applications Laboratory) website. The header includes the NCAR UCAR logo and the tagline "science • serving • society". The navigation menu includes "RAL HOME", "WHO WE ARE", "WHAT WE DO", "SOLUTIONS", and "WORK WITH US". The main content area is titled "What We Do" and features a section for "WRF-SOLAR™" with a satellite-style image of solar irradiance. Below this is an "Overview" section with text describing the WRF-Solar model's capabilities. To the right, there are sections for "RENEWABLE ENERGY PROJECTS" and "CONTACT" with contact information for Pedro Jimenez Munoz.

FARMS provides WRF-Solar an option to rapidly forecast GHI and DNI.

<https://ral.ucar.edu/projects/wrf-solar>

FARMS is used to promote short-term solar forecast from satellite or surface measurements.

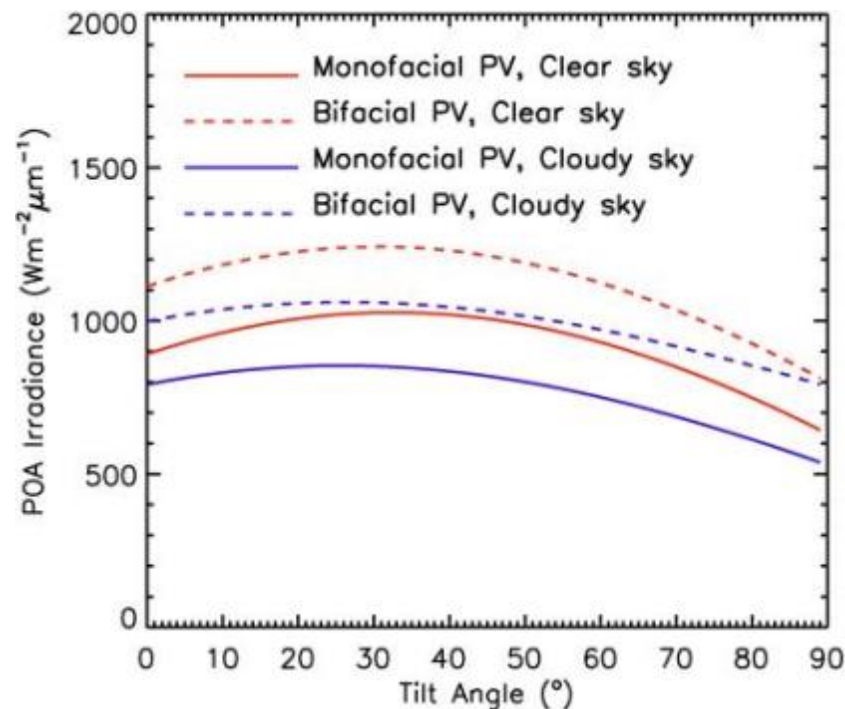


Applications and Future Work



Photo by Thomas Kelsey, NREL 38319.

FARMS-NIT will upgrade NSRDB with spectral irradiances in the POA.



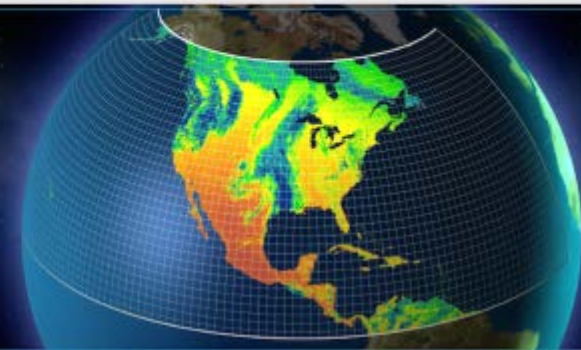
National Solar Radiation Database (NSRDB)

Home About Data Sets Resources Contact

Site: Global Horizontal Irradiance
Location: Earth, North America
Site: Newark NJ, 2010
Time: 120 hours, Mountain Time Zone
Spatial Resolution: 4 km



Analysis
Precipitation, Albedo
Atmosphere
Water Vapor
Cloud Cover



Q&A or Thank you

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL/PR-5D00-70625