NREL
Transforming ENERGY

Modeling of Spectral Irradiance in the POA using GOES Satellite Data

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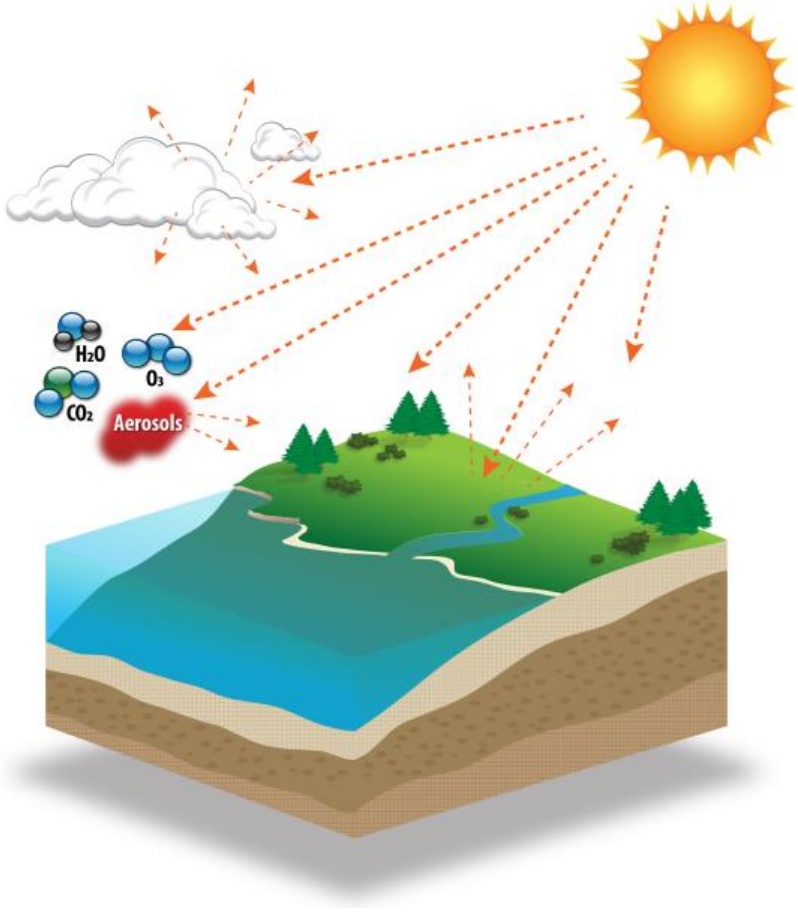
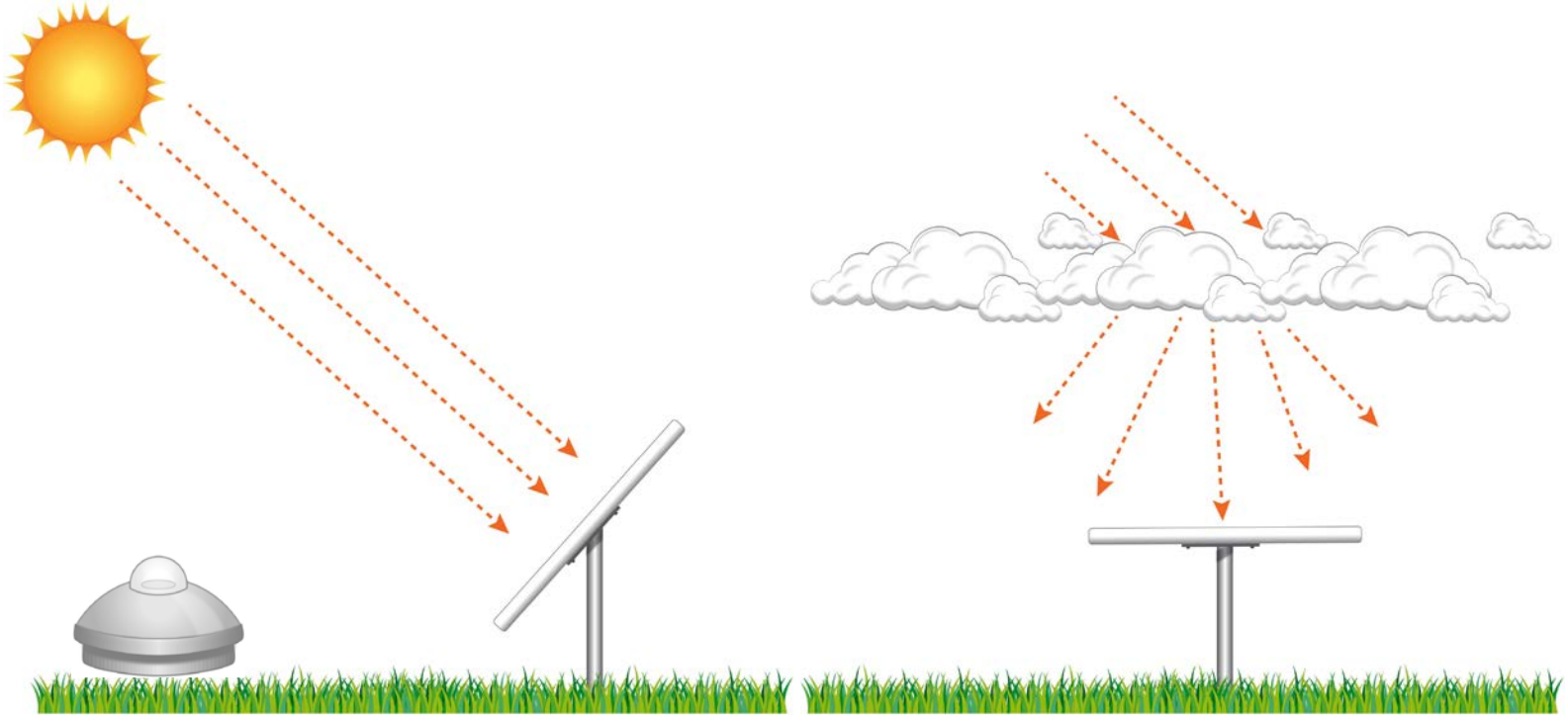
Radiative transfer model for solar energy



- Consider interactions with atmospheric constituents and land surface.
- Solar energy research has unique requirements on models.

Solar radiation on tilted surfaces

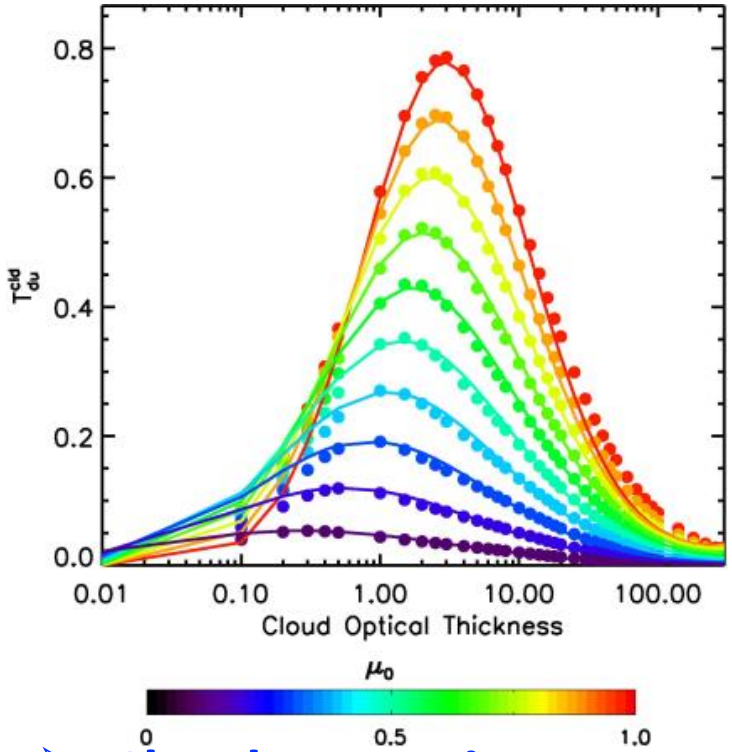


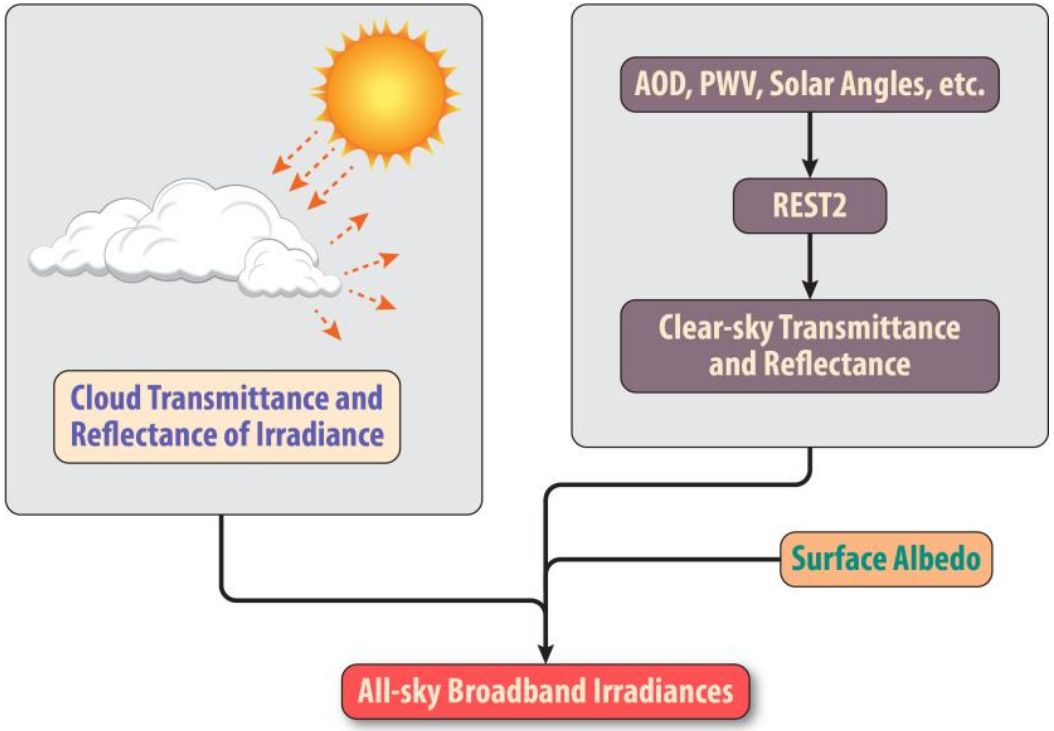
- POA irradiance = direct + diffuse + surface reflection
- Solar energy research is more sensitive to model efficiency

Solar energy research requires spectral radiation

PV systems are dominated by spectral radiation, spectral response of semiconductor materials, and solar cells to split spectral radiation.

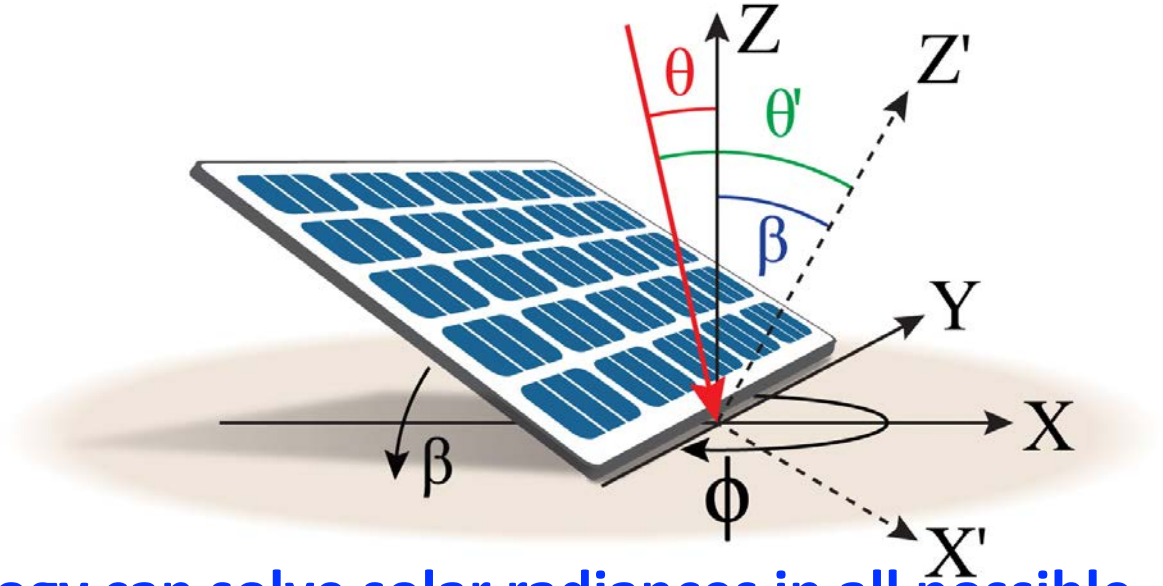
Fast All-sky Radiation Model for Solar applications (FARMS)





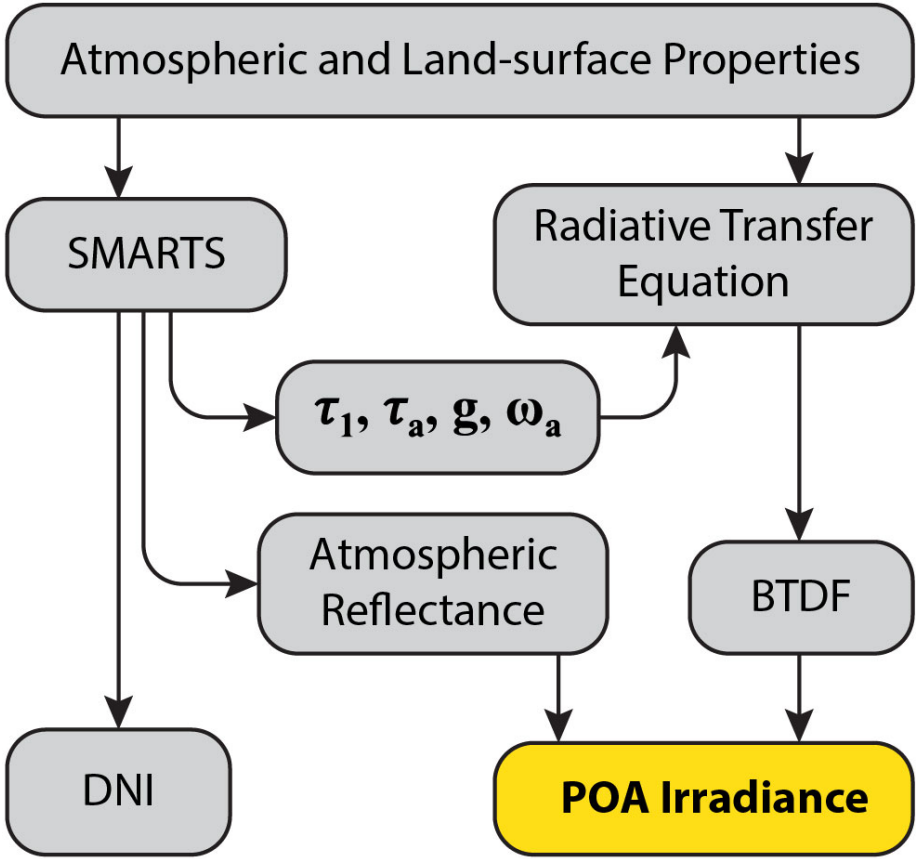
- Cloud transmittances can be parameterized as exponential functions of cloud optical thickness and solar zenith angles.

FARMS for Narrowband Irradiances on Tilted Surfaces (FARMS-NIT)



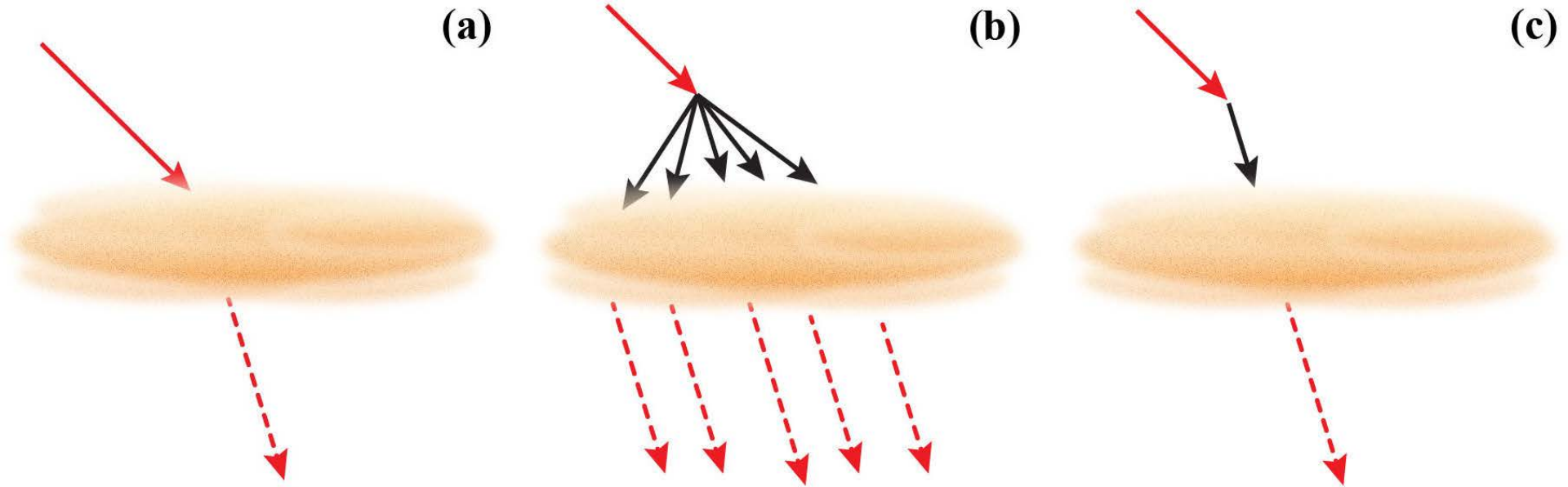
- Models for meteorology can solve solar radiances in all possible directions.
- Models for solar energy use regression functions to empirically link with long-term observations of GHI.

FARMS-NIT for clear-sky conditions



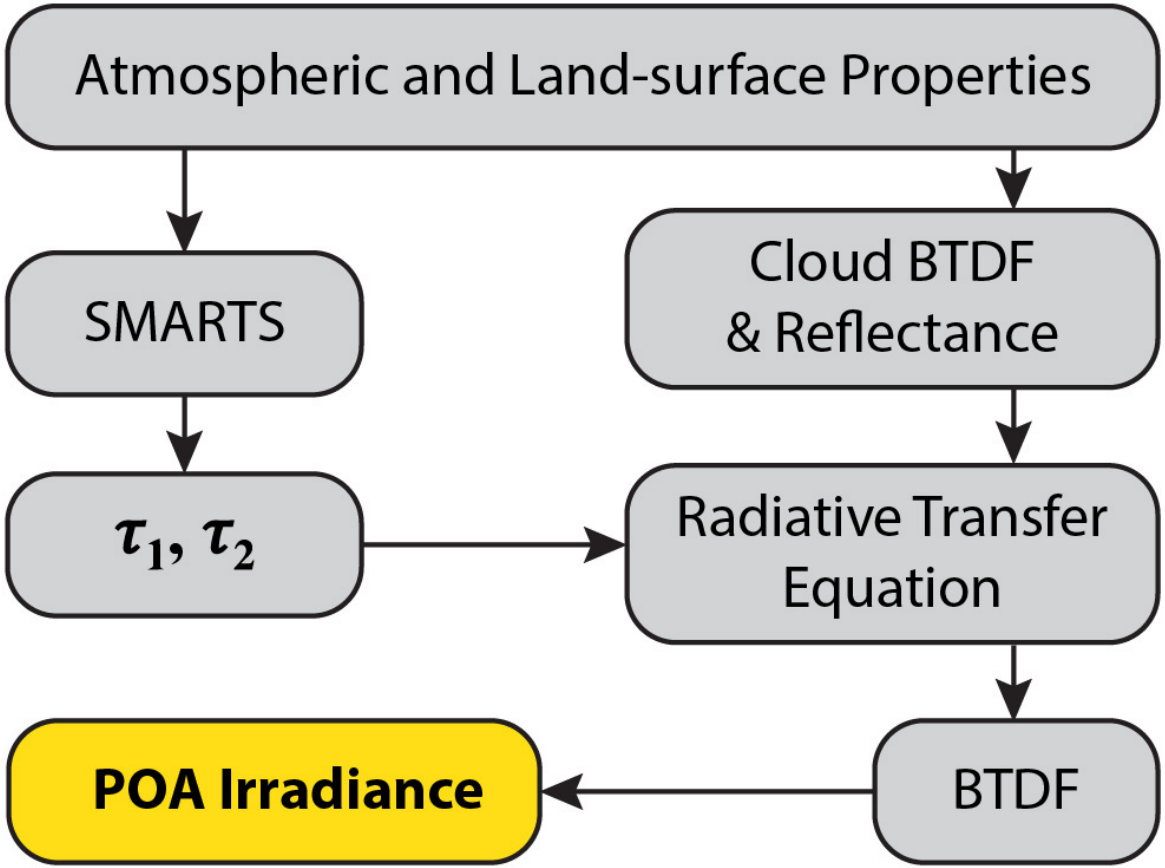
- The transmittances of aerosols are computed using the single-scattering assumption.
- Spectral radiances on the surface are computed by solving the radiative transfer equation for all possible photon paths.

FARMS-NIT for clear-sky conditions



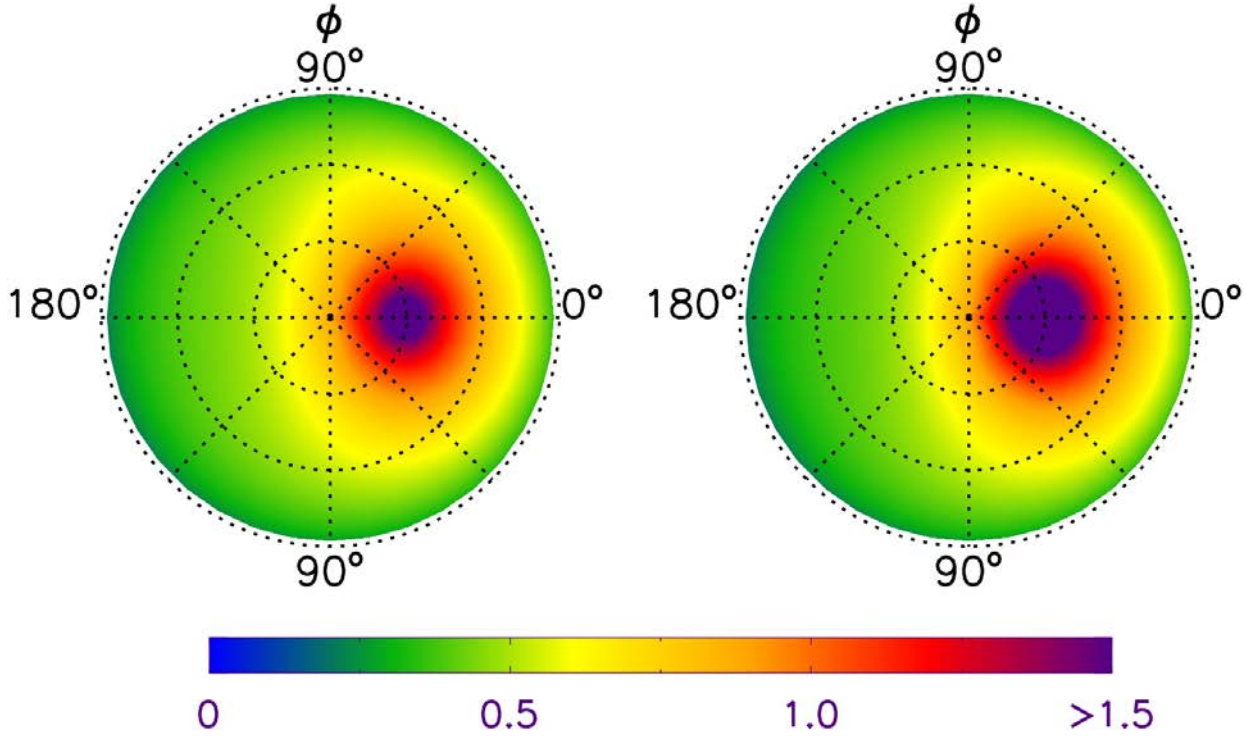
(a) Absorbed by the atmosphere and scattered by aerosol.
(b) Scattered in the atmosphere and scattered again by aerosol.
(c) Scattered in the atmosphere and absorbed by aerosol.

FARMS-NIT for cloudy-sky conditions



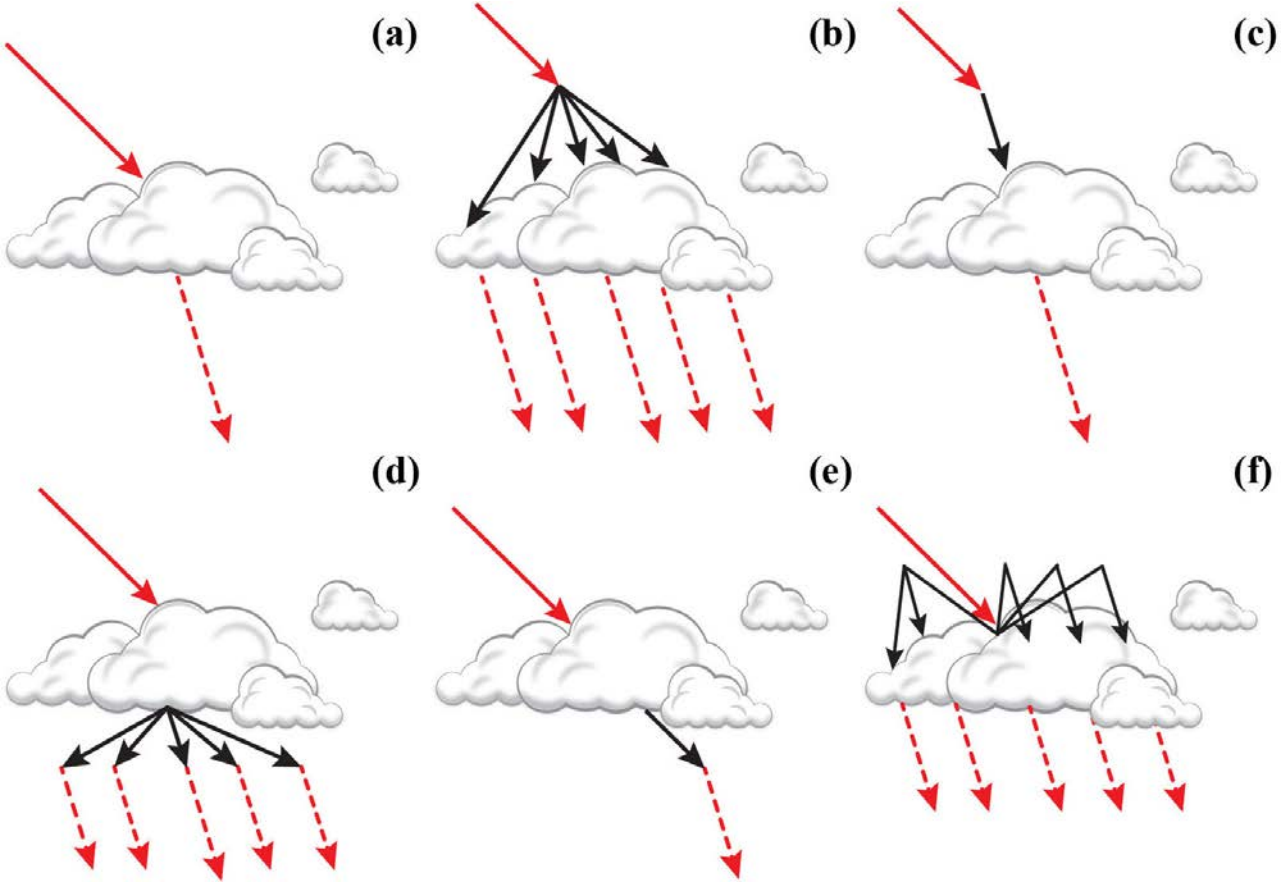
- **The transmittance of clouds is given by a pre-computed lookup table for all possible cloud conditions and solar and viewing angles.**

FARMS-NIT for cloudy-sky conditions



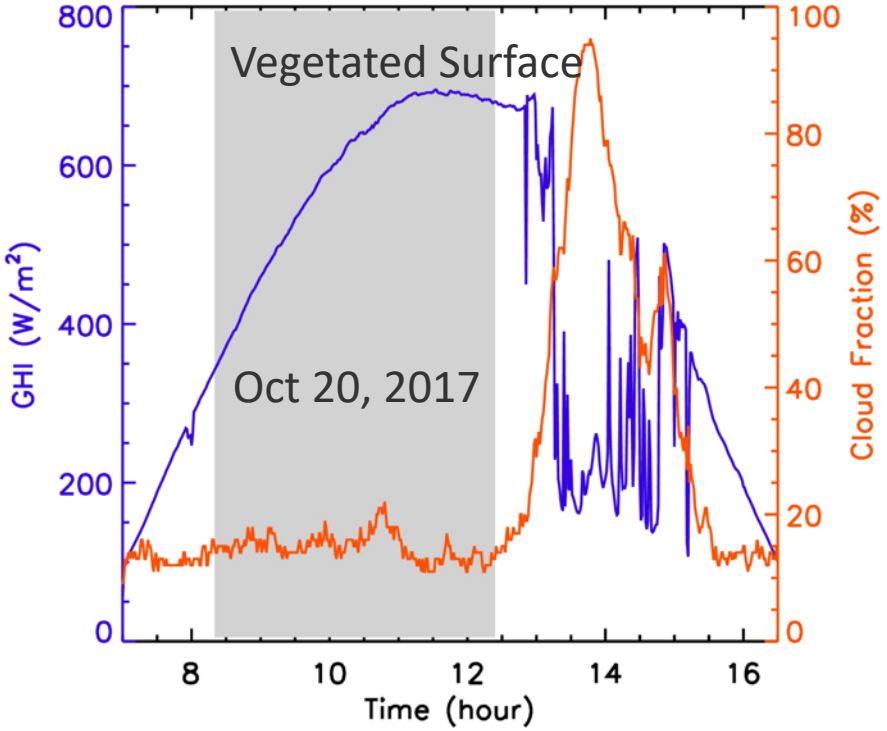
Cloud BTDF for water (left) and ice (right) clouds for $\tau = 5$, $\mathrm{De} = 10\ \mu m$, $\theta_0 = 30°$. The viewing zenith angle increases from 0 to 90 degree along the radial direction.

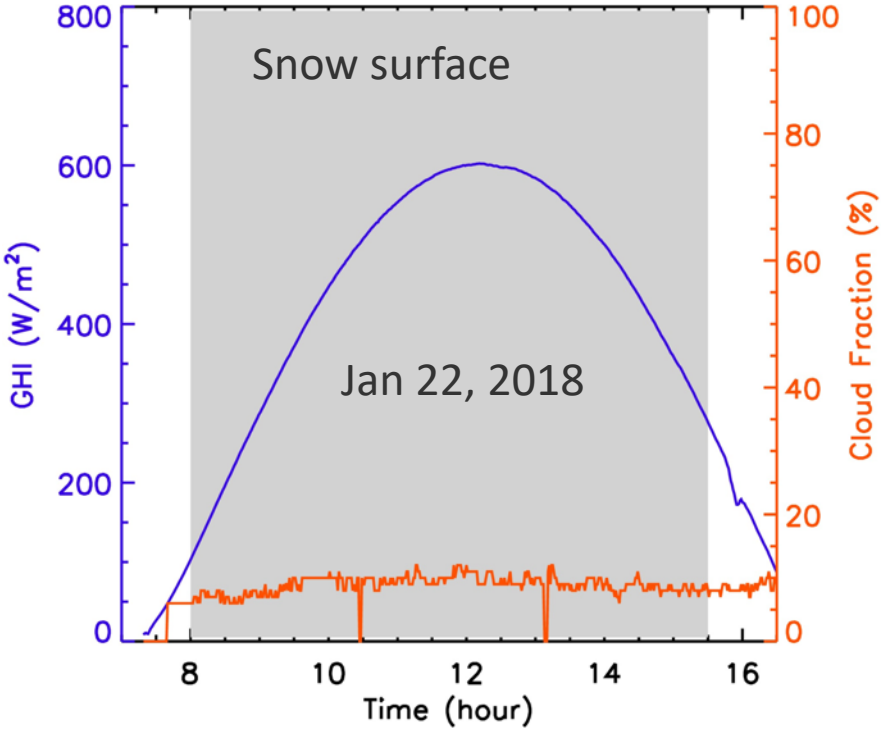
FARMS-NIT for cloudy-sky conditions



- The first three photon paths are the same as the clear-sky model.
- Additional photon paths are considered when Raleigh scattering occurs under the cloud.

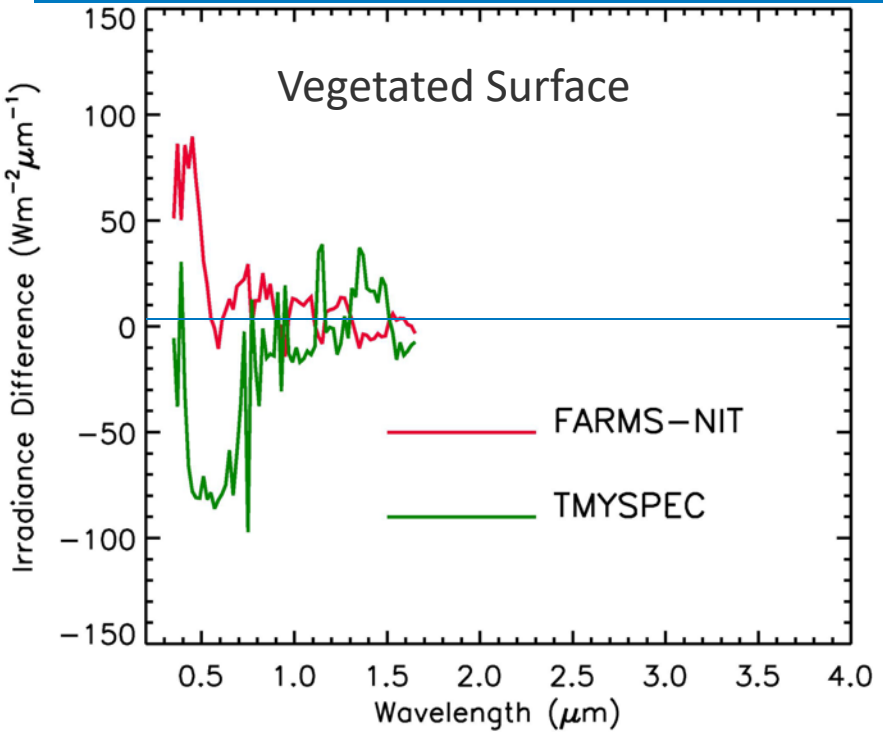
Evaluation of FARMS-NIT

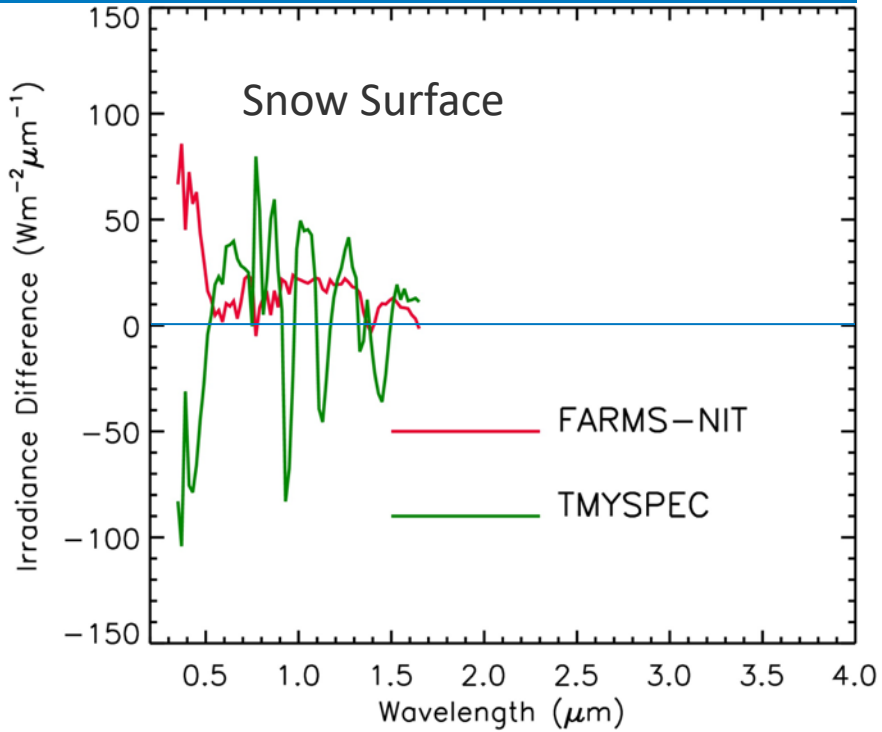




- **Measurements from the EKO WISER spectroradiometer on a 1-axis tracker is compared with FARMS-NIT and TMYSPEC.**

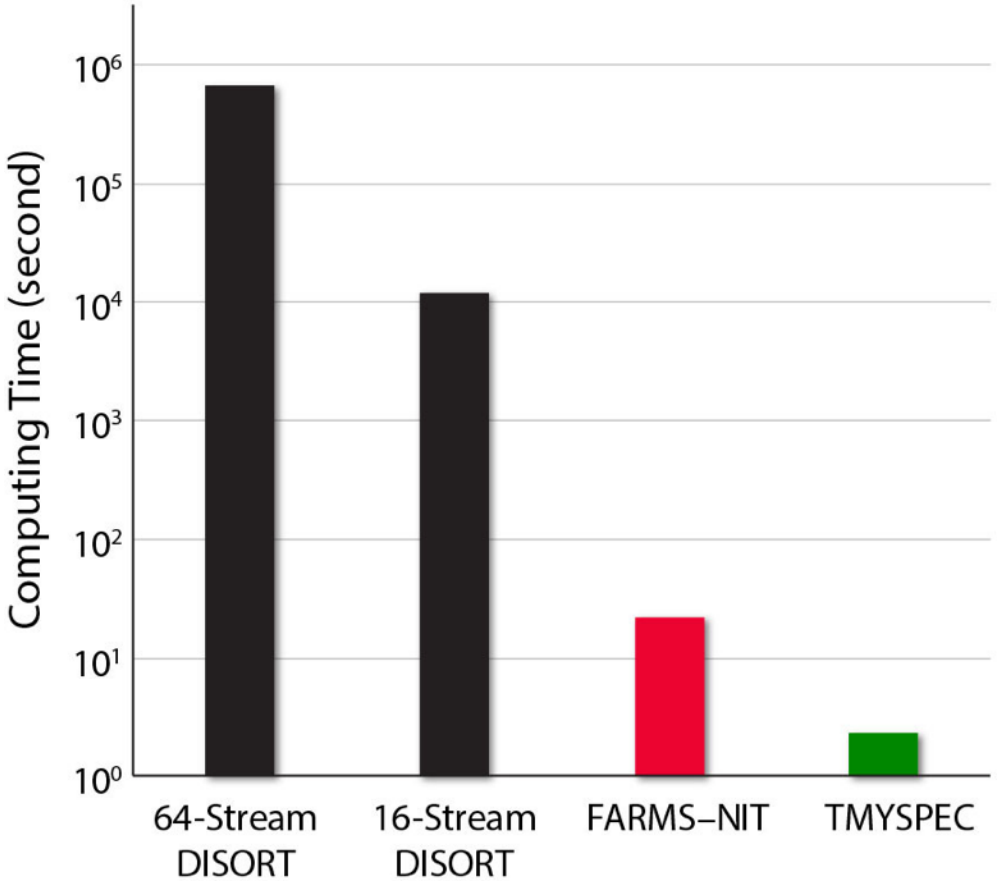
Evaluation of FARMS-NIT





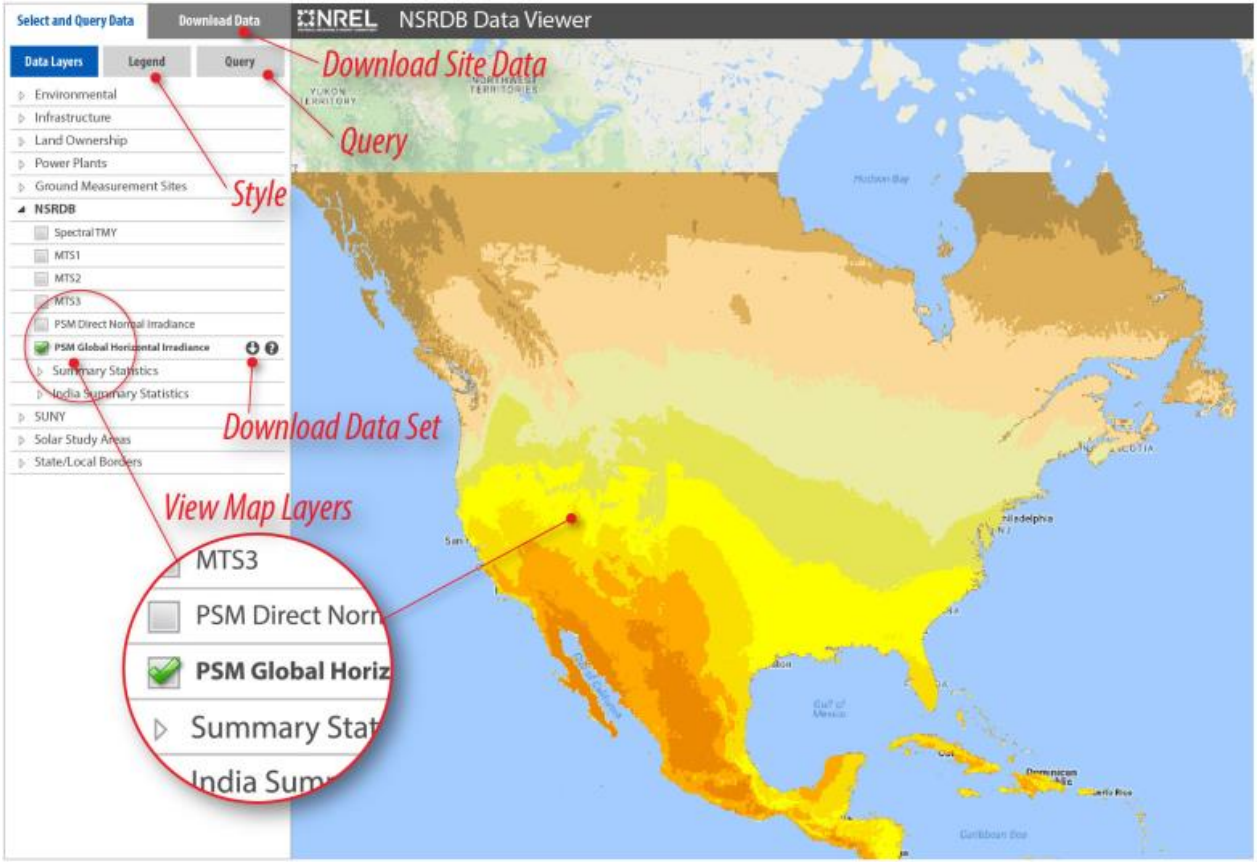
- **FARMS-NIT has a much better performance than TMYSPEC, especially on the snow day.**

Evaluation of FARMS-NIT



- For computing hourly spectral POA irradiances for a day, FARMS-NIT consumes 21.9 seconds.
- With our current server that can use multiple-processors we can compute and deliver spectral data for 1 year in ~2 minutes.

Spectral data using GOES data



- **With users' selection of location and PV orientations, we compute and deliver the spectral data using the NSRDB website.**

https://nsrdb.nrel.gov or the Application Programming Interface

Q&A or Thank you

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