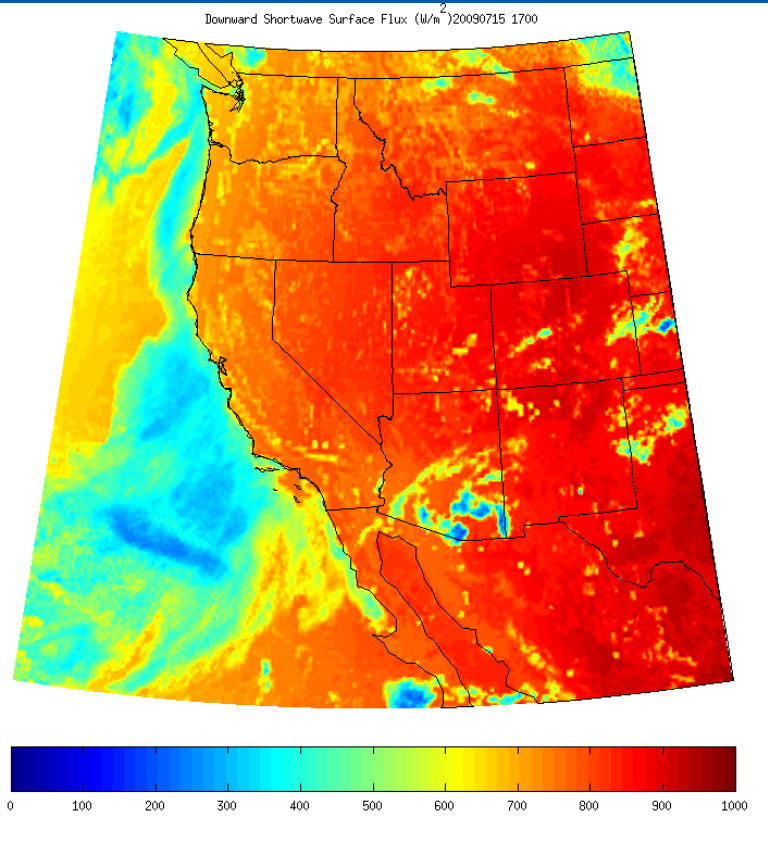
National Renewable Energy Laboratory
Innovation for Our Energy Future

A Physical Method for Calculating Surface Radiation from Geostationary Satellites



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How do we measure/model solar radiation?

Ground based instruments (radiometers, pyrheliometers, pyranometers)

Advantages: accurate, high temporal resolution.

Disadvantages: local coverage, regular maintenance and calibration.

Satellite based models (geostationary, polar orbiters)

Advantages: global coverage, reasonably long time series,

Disadvantages: spatial and temporal resolution, complicated retrieval process, accuracy depends on information content of satellite channels.

Numerical models (global, regional, mesoscale)

Advantages: global coverage, long time series (reanalysis data), increasing computing capability results in increasing resolution.

Disadvantages: level of accuracy especially in cloud formation and dissipation (initialization and model physics issues).

NOTE: Methods that combine all 3 will ultimately provide the best solutions.

What impacts surface radiation

First order:

(a) Clouds (Ice and water droplets)

- –Scatter solar radiation
- – Ice clouds are more forward scattering that water clouds.
- –Smaller droplets scatter more.

(b) Aerosols (mineral dust, soot etc.)

- –Most impact in clear sky situations.
- –Absorb and scatter solar radiation (depends on aerosol type)

Second order:

(a)water vapor and ozone

- Absorb solar radiation.
- Elevation associated molecular scattering

(b)3-dimensional clouds effects

- Cloud edge scattering with enhancement in surface radiation

How do satellites model surface radiation?

Empirical Approach:

- –Build model relating satellite measurements and ground observations.
- –Use those models to obtain solar radiation at the surface from satellite measurements.

Semi-Empirical Approach:

- –Retrieve “cloud index” from visible satellite measurements
- –Use clear sky radiative transfer models and scale by cloud index

Physical Approach:

- –Retrieve cloud and aerosol information from satellites
- –Use the information in a radiative transfer model

The GOES Solar Insolation Products (GSIP): A physical modeling approach

- Developed by NOAA for polar orbiting AVHRR instrument (Clouds from AVHRR-Extended: CLAVR-X) and adapted for geostationary satellites (GOES and Meteosat/MSG-Seviri)
- Physical modeling approach with two steps for estimating cloud properties and surface radiation from geostationary satellites.
  - **Step 1**: Retrieve cloud properties from the Geostationary Operational Environmental Satellite (GOES) visible and infrared channels.
  - **Step 2**: Calculate surface radiation using a radiative transfer model with cloud information from Step 1 as input.

Step1 : Retrieving Cloud Properties: Inputs

1. **Reflectance and radiance from GOES satellites** (0.64 µm, 3.9 µm, 6.5 µm and 10.7 µm channels)
2. **Land mask database** (University of Maryland 8 km global database)
3. **Surface type information** (Maryland's 8 km global database with pixels being reclassified as snow/ice with International Geosphere/Biosphere Program database)
4. **Digital elevation map** (United States Geological Service GTOPO30 database)
5. **Monthly climatologies of Normalized Difference Vegetation Index (NDVI)** (AVHRR Pathfinder Atmospheres (PATMOS))
6. **Sea Surface Temperature (SST)** (monthly climatology product from NOAA)

Step 1: Retrieving Cloud Properties: Outputs

Cloud properties from GOES at 4 km resolution:

- **Cloud Masking:**
  - Clear, Partly Cloudy, Partly Clear, Cloudy
- **Cloud Type:**
  - Liquid, Mixed, Ice, Cirrus, Multi-layer
- **Cloud properties:**
  - Optical Depth, effective radii of particles, cloud top temperature, cloud top pressure, liquid water path, ice water path

References:

Heidinger, A. K., 2003: Rapid daytime estimation of cloud properties over a large area from radiance distributions. *J. Atm. Oceanic Tech.,* **20,** 1237-1250**.**

Pavolonis, M., A. K. Heidinger, T. Uttal, 2005: Daytime Global Cloud Typing from AVHRR and VIIRS: Algorithm Description, Validation, and Comparisons. *J. Appl. Meteor.,* **44,** 804-826**.**

Stowe, L. L., P. A. Davis, and E. P. McClain, 1999: Scientific basis and initial evaluation of the CLAVR-1 global clear cloud classification algorithm for the Advanced Very High Resolution Radiometer. *J. Atmos. Oceanic Technol.,* **16,** 656–681.

Step 2: Surface radiation calculations: Inputs & Outputs

GHI (currently 1/8 degree or approximately 12 km resolution)

Input

Cloud Properties from Step 1

Aerosol radiative properties from clear sky

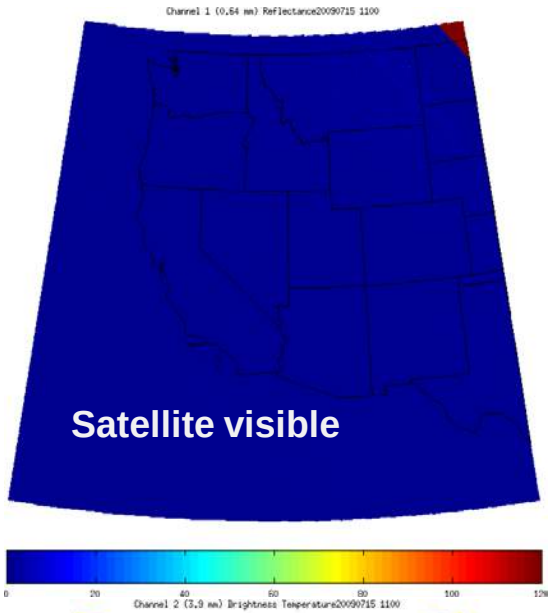
Output

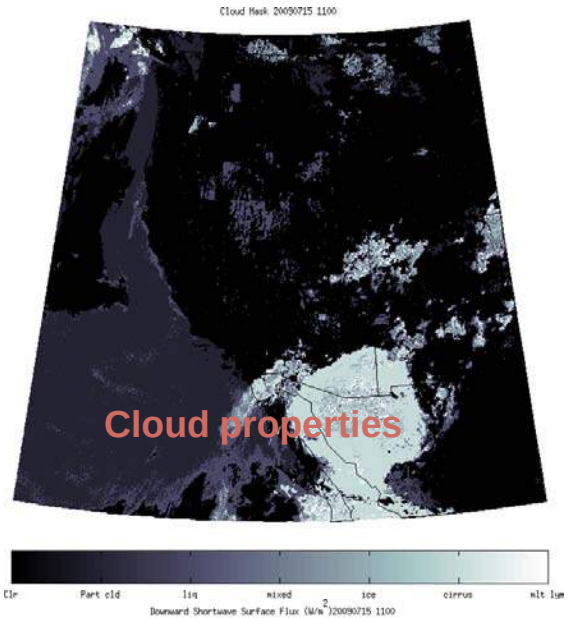
Ice cloud fraction, Water cloud fraction, Mean optical depth, dominant cloud type, Mean Outgoing Longwave Radiation (OLR), Total Precipitable Water (TPW), Shortwave Downward Diffuse, Shortwave downward total (GHI), Visible downward total (0.4 – 0.7 μm)

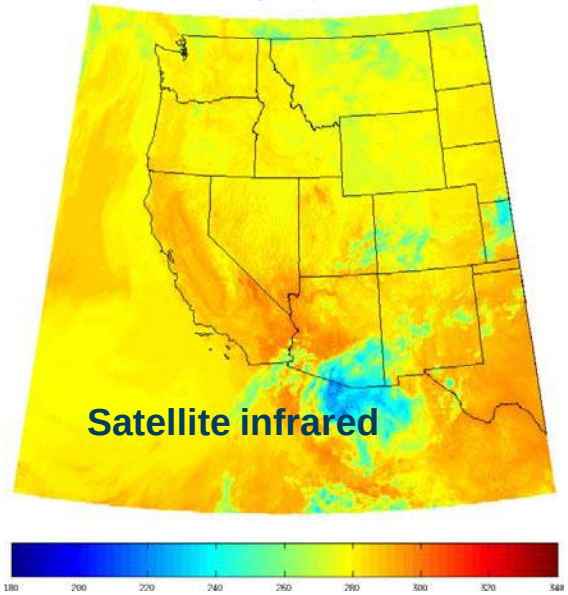
Reference:

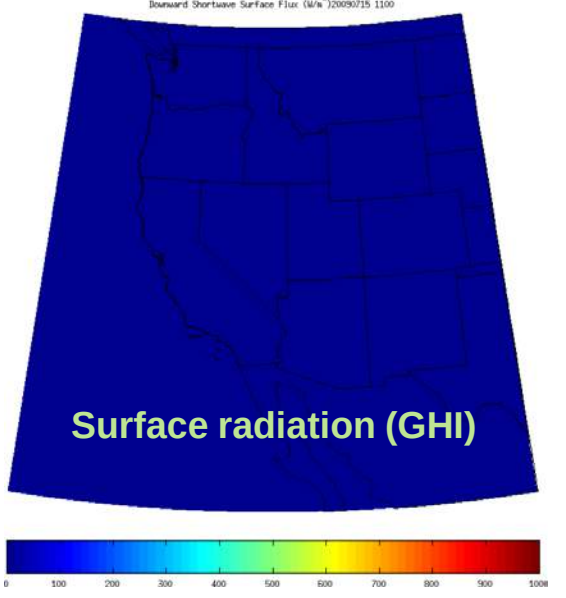
Istvan Laszlo, Pubu Ciren, Hongqing Liu, Shobha Kondragunta, J. Dan Tarpley, Mitchell D. Goldberg Publication Date, 2008: Remote sensing of aerosol and radiation from geostationary satellites, *Adv. Space Res*., **41**,11,1882-1893

Results: Satellite Imagery, Retrieved Clouds and Surface Radiation from GOES West using GSIP





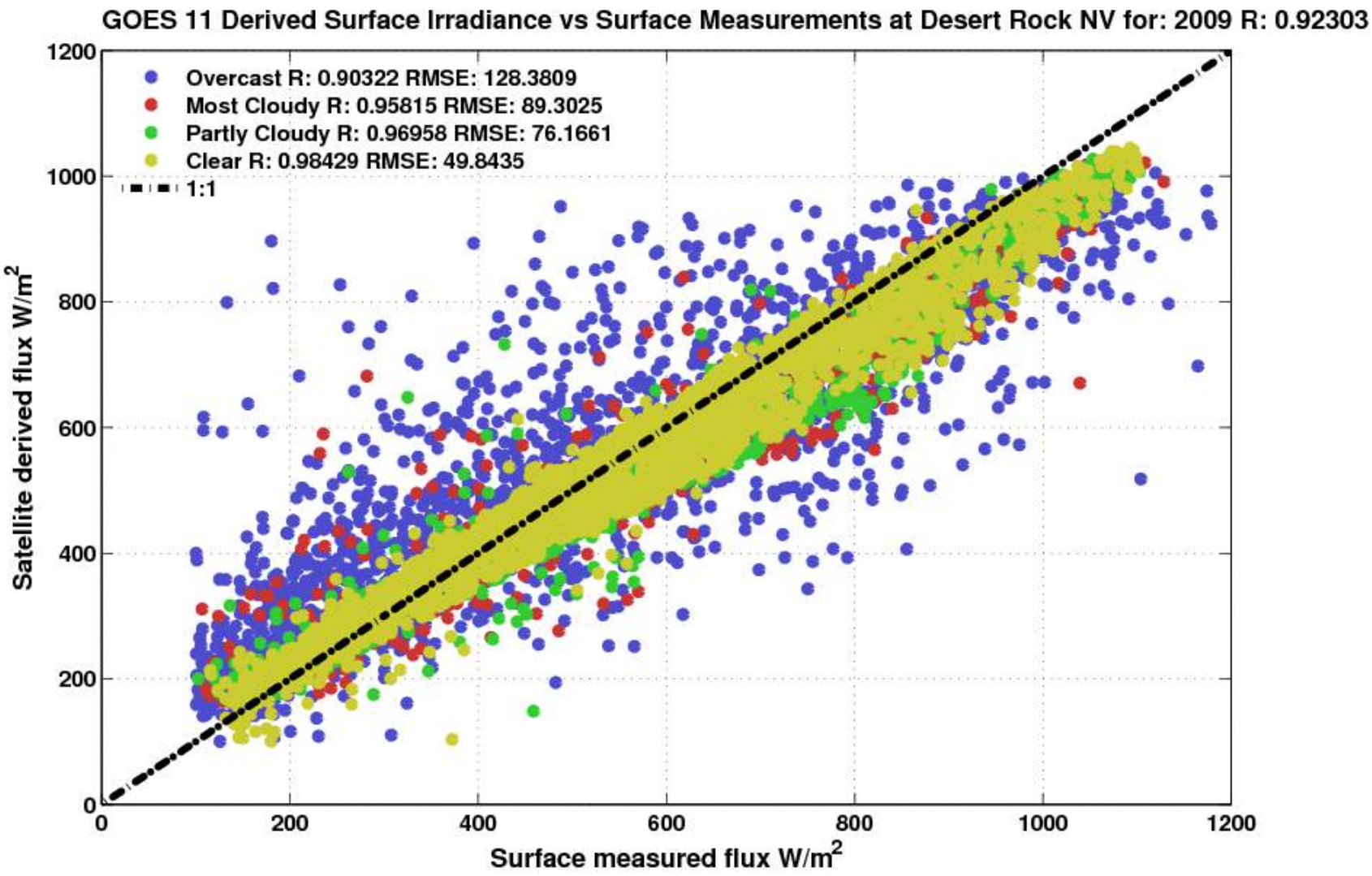




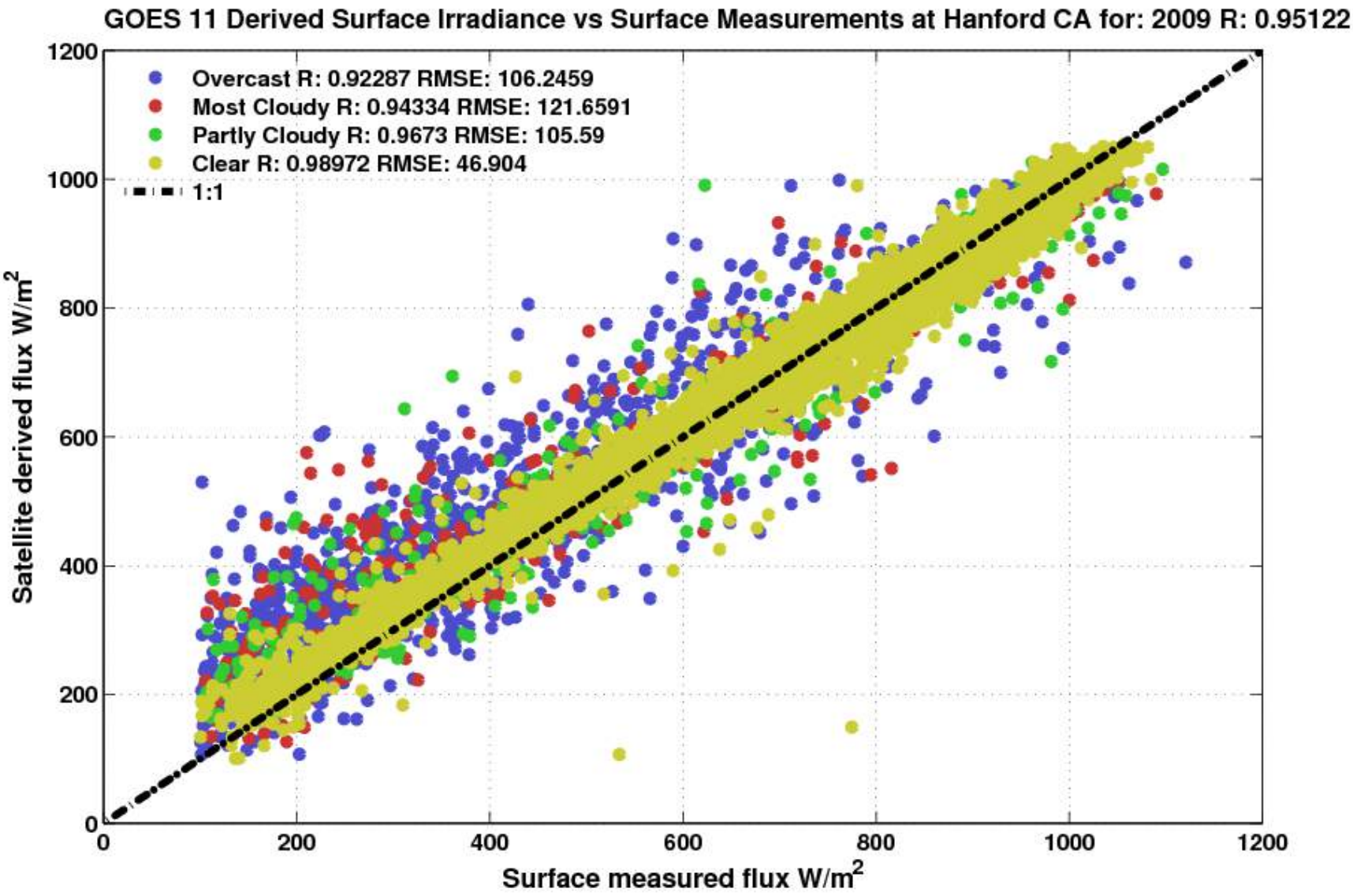
July 15, 2009

Satellite based cloud and surface radiation product using NOAA's Global Solar Insolation Products (GSIP) Algorithm

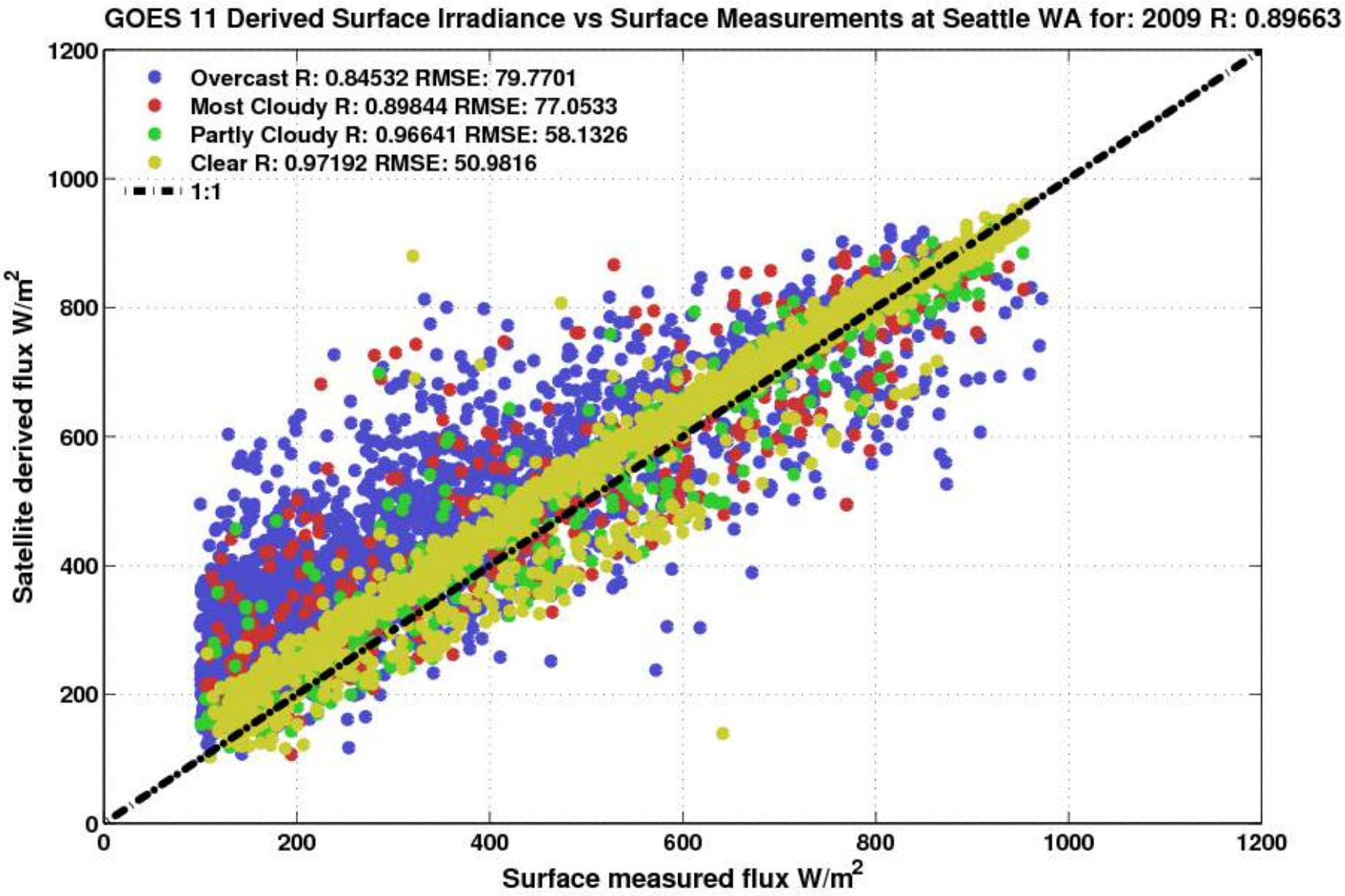
GHI Comparison with NOAA surface measurements: Desert Rock, NV



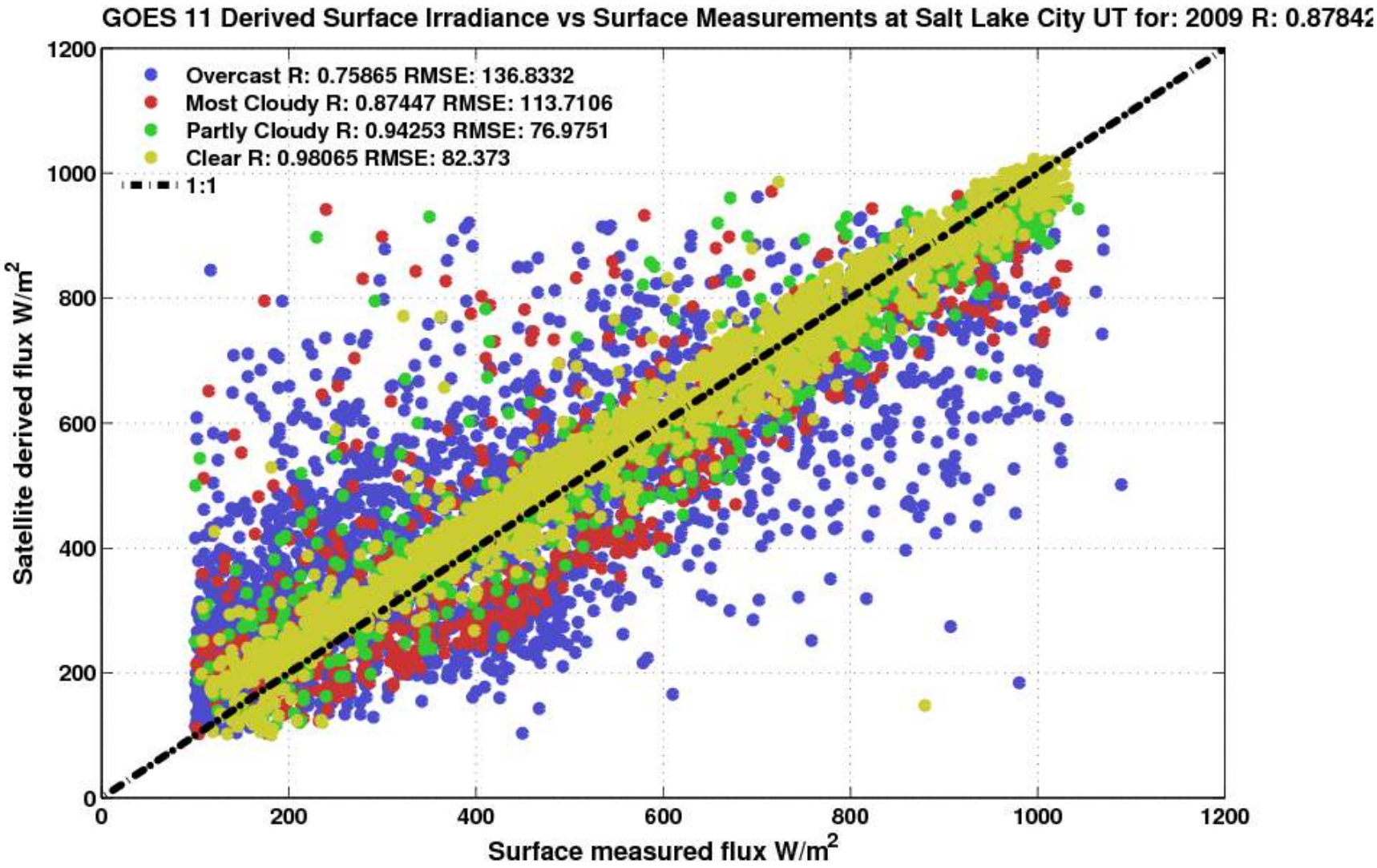
GHI Comparison with NOAA surface measurements: Hanford CA



GHI Comparison with NOAA surface measurements : Seattle, WA



GHI Comparison with NOAA surface measurements : Salt Lake City, UT



Comparison with surface measurements

Data Type		Desert Rock, NV	Seattle, WA	Hanford, CA	Salt Lake City, UT
All	R	0.92	0.90	0.95	0.88
	RMSE	100	129	88	134
Overcast	R	0.90	0.85	0.92	0.76
	RMSE	128	80	106	137
Partly Clear	R	0.96	0.90	0.94	0.88
	RMSE	89	77	122	114
Partly Cloudy	R	0.97	0.97	0.97	0.94
	RMSE	76	58	106	77
Clear	R	0.98	0.97	0.99	0.98
	RMSE	50	50	47	82

Notes:
Overcast (75%-100% cloud cover); Partly clear (50%-75%); Partly cloudy (25%-50%); Clear (0%-25%)
Data from 2009
RMSE in W/m^2

Conclusions & Future Work

- Physical method for calculating surface radiation has been developed and implemented.
- Preliminary comparisons for 1 year of data shows reasonable results with errors comparable with other existing methods.
- Advantage of method is the availability of cloud masking and properties.
- Use of multiple satellite channels improves information content in the retrieval method.
- DNI calculations are being implemented.
- High resolution datasets for testing are being created.

Thank you!

Question/Comments