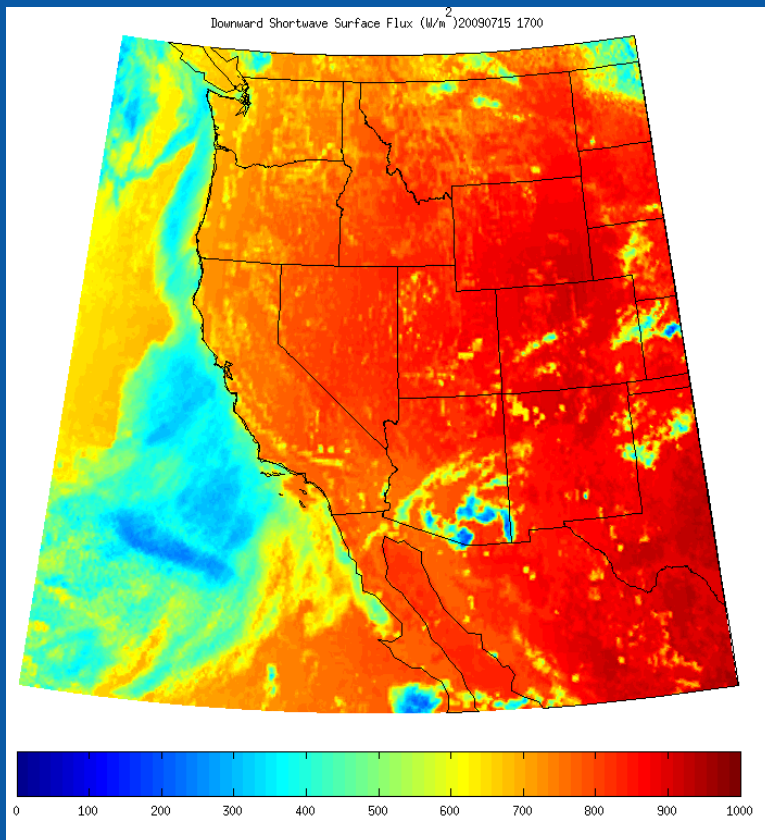


A PHYSICAL METHOD TO COMPUTE SURFACE RADIATION FROM GEOSTATIONARY SATELLITES



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Why do we need solar radiation measurement and modeling?

- To provide accurate resource assessment for feasibility studies.
- To verify plant performance.
- To forecast solar resource for estimating plant output.
- To understand resource variability and its relation to plant output.
- To forecast variability (sub-hourly to climate scale) and its impact on plant output.

How do we measure/model solar radiation?

Ground based instruments (radiometers, pyrhelimeters, 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 than water clouds.
- Smaller droplets scatter more.

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

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

Second order:

(a) water vapor and ozone

Absorb solar radiation.

(b) Rayleigh scattering

(c) 3-dimensional clouds effects

Cloud edge scattering with enhancement in surface radiation

How to model surface radiation from satellite measurements?

Empirical Approach:

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

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)
- Physically based two step algorithms 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

Output

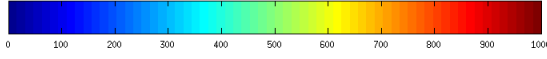
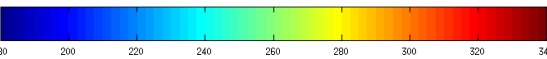
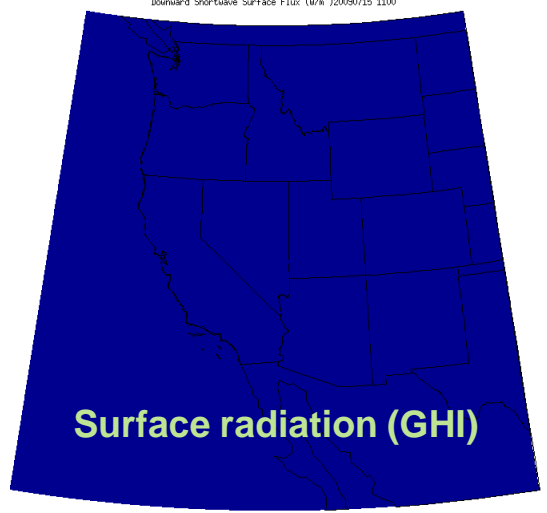
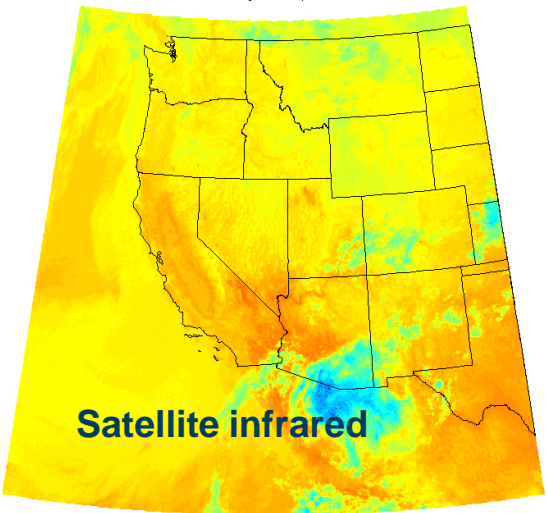
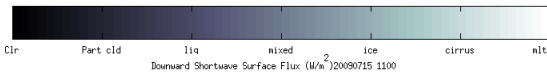
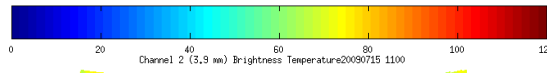
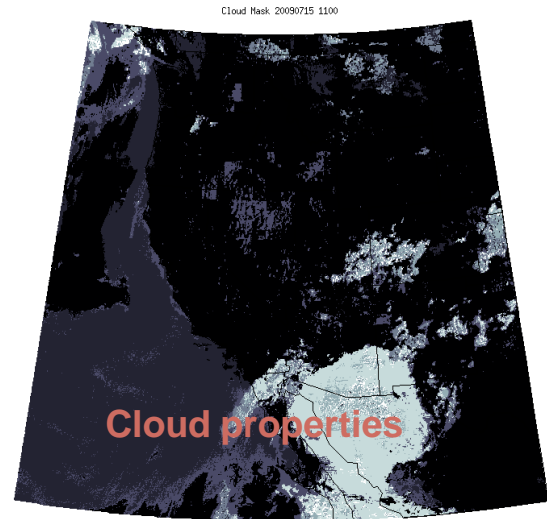
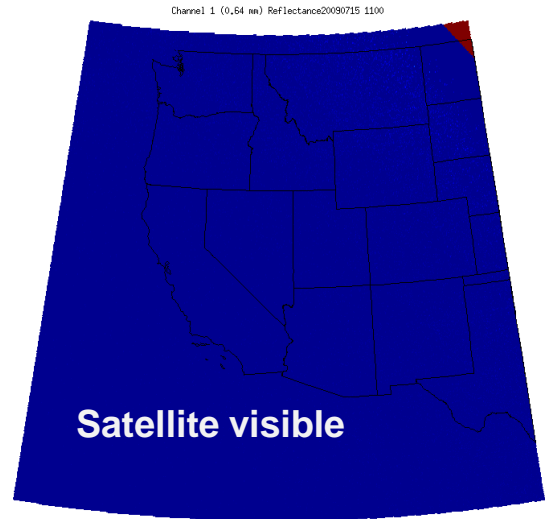
Ice cloud fraction, Water cloud fraction, Mean optical depth, dominant cloud type, Mean Outgoing Longwave Radiation (OLR), Total Precipitable Water (TPW), Shortwave Downward Diffuse, Shortwave downward total (GHI), Visible downward total (0.4 – 0.7 μm)

Reference:

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

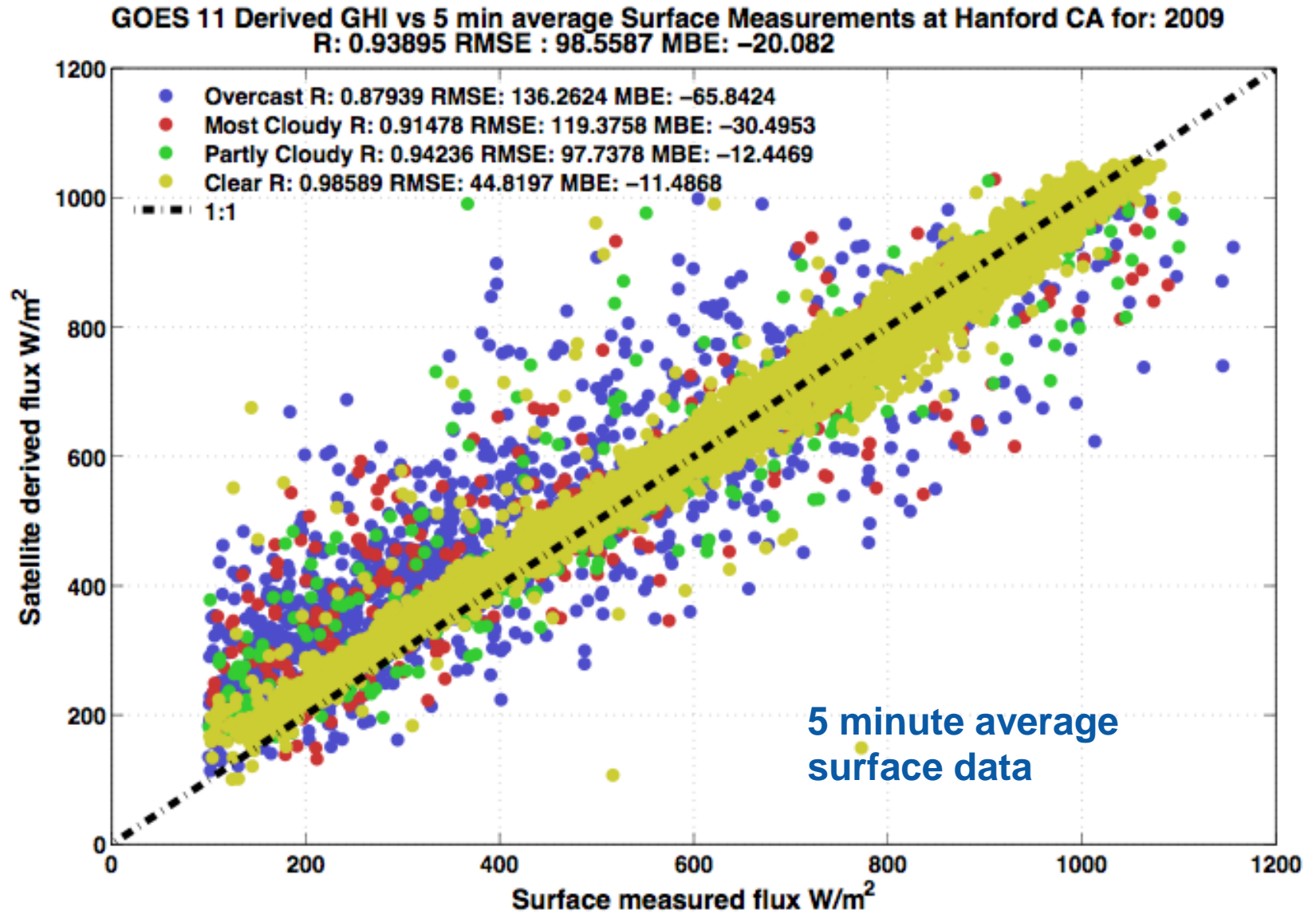
Results: Satellite Imagery, Retrieved Clouds and Surface Radiation from GOES West using GSIP

July 15, 2009

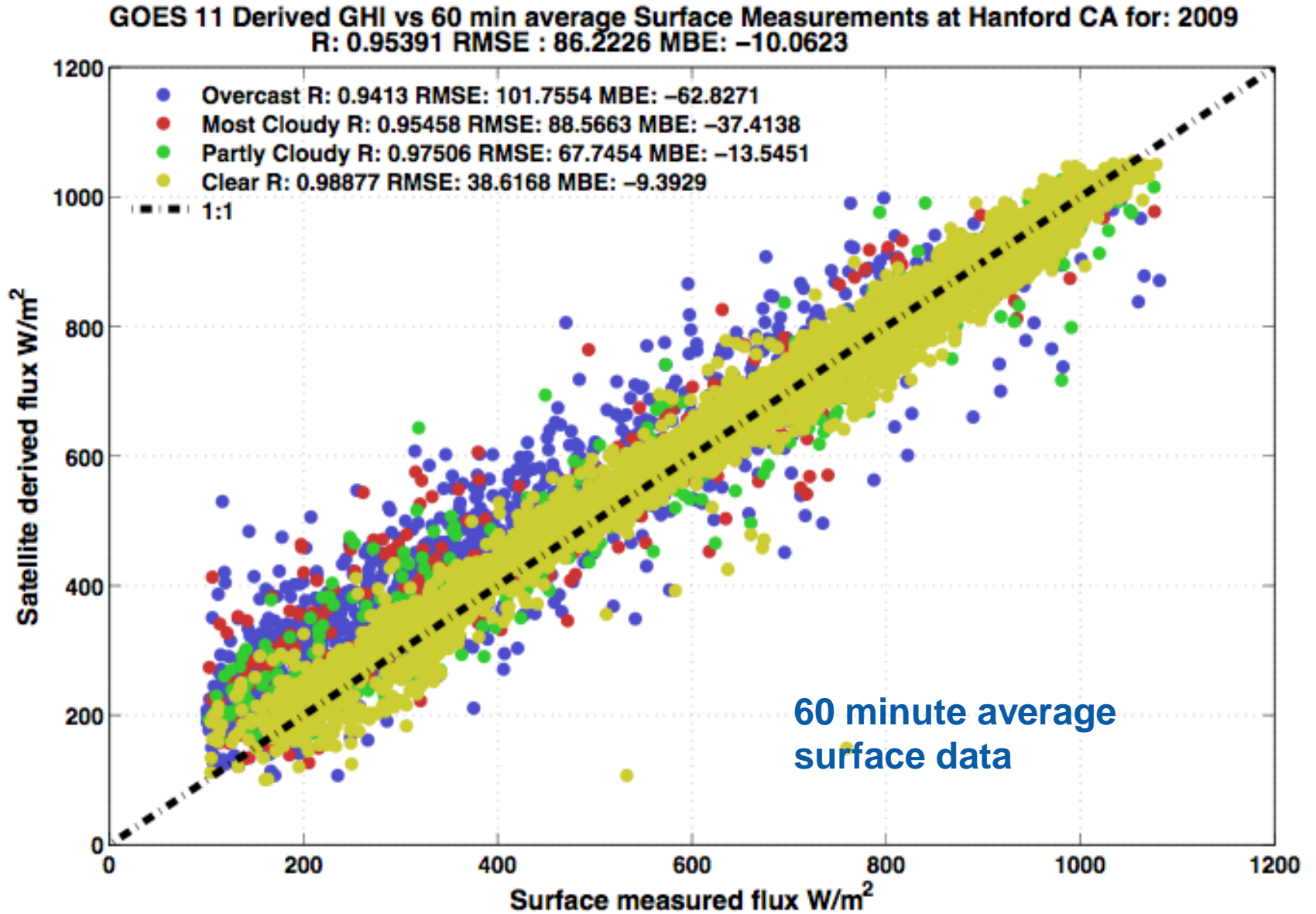


Satellite based cloud and surface radiation product using NOAA's Global Solar Insolation Products (GSIP) Algorithm

GHI Comparison with NOAA surface measurements: Hanford CA



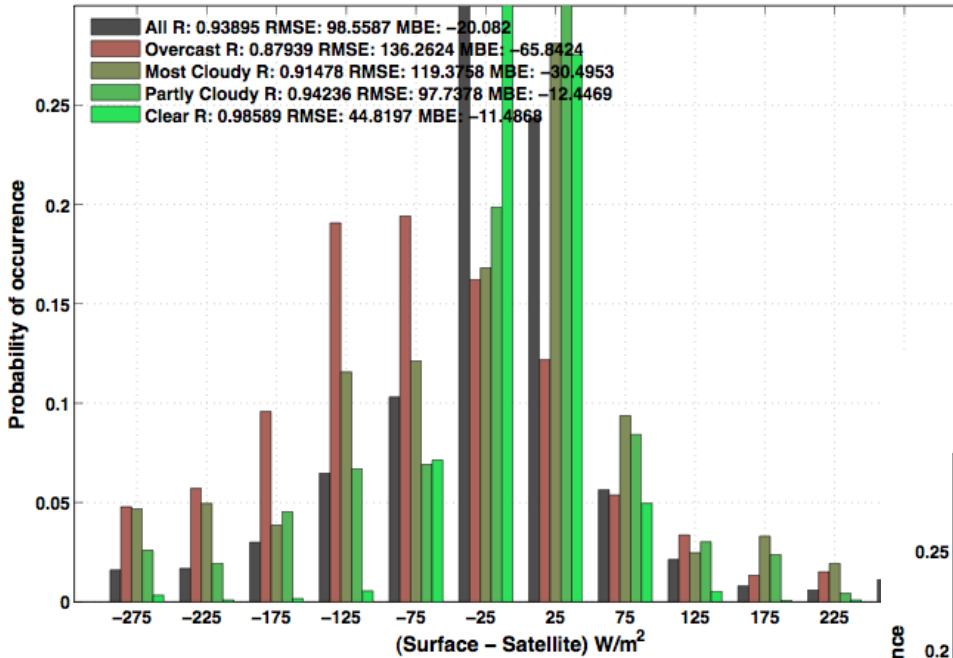
GHI Comparison with NOAA surface measurements: Hanford CA



GHI Comparison with NOAA surface measurements: Hanford, CA

GOES 11 Derived GHI vs 5 min average Surface Measurements at Hanford CA for: 2009

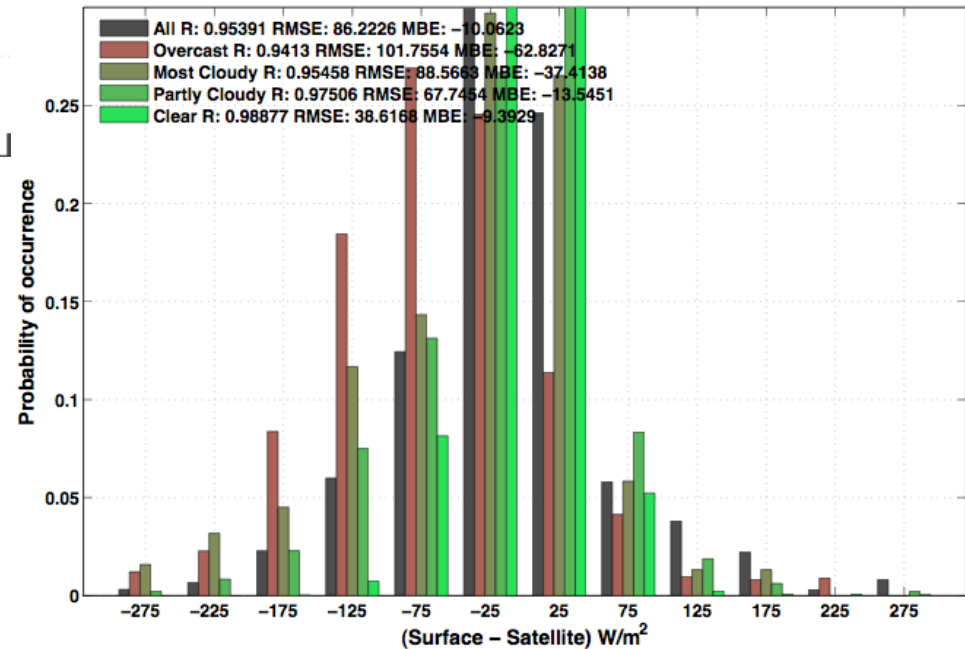
R: 0.93895 RMSE : 98.5587 MBE: -20.082



5 minute average

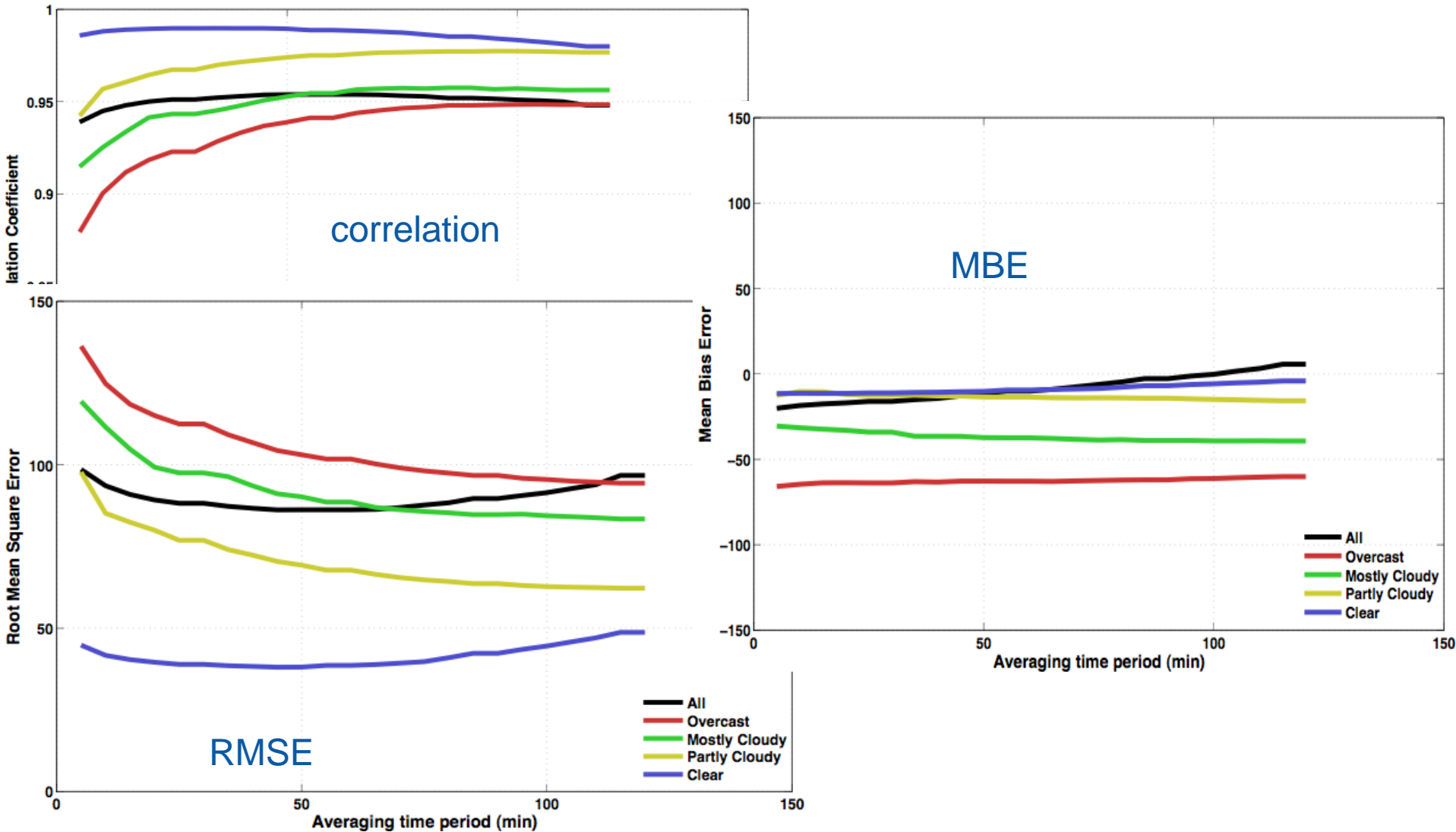
GOES 11 Derived GHI vs 60 min average Surface Measurements at Hanford CA for: 2009

R: 0.95391 RMSE : 86.2226 MBE: -10.0623



60 minute average

GHI Comparison with NOAA surface measurements: Hanford, CA



Comparison of Satellite retrievals when compared to 5, 30 and 60 minute surface averages



Conclusions & Future Work

- Physical method for calculating surface radiation has been developed and implemented.
- Preliminary comparisons for 1 year of data shows good results when compared with other existing methods.
- Advantage of method is the availability of cloud masking and cloud properties.
- Use of multiple satellite channels improves information content in the retrieval method.
- Independent DNI calculations are being implemented.
- Satellite datasets compare best with averaged surface datasets (around 60 minutes).
- High resolution datasets for testing are being created.

Gracias por su atención!

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