Global high-resolution land products of downward shortwave radiation and photosynthetically active radiation from MODIS, VIIRS and other data

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- Status of MCD18 C6 products
- C61 refinement
- Researches on algorithm improvement
- Adaption to S-NPP VIIRS data
- Summary

Need for high-resolution DSR/PAR products

- Current global radiation products have coarse spatial resolution (>1°) primarily for atmospheric modeling, and do not account for many local features, such as urbanization.
- Land applications require the high spatial resolution (~1km) :
  - Ecosystem modeling (say, MOD17 NPP product) requires high-resolution products of PAR;
  - Hydrological modeling (ET, MOD16);
  - Other applications (e.g., drought monitoring, clean renewable solar energy).

Downward shortwave radiation and PAR products

Current global incident **shortwave radiation** satellite products

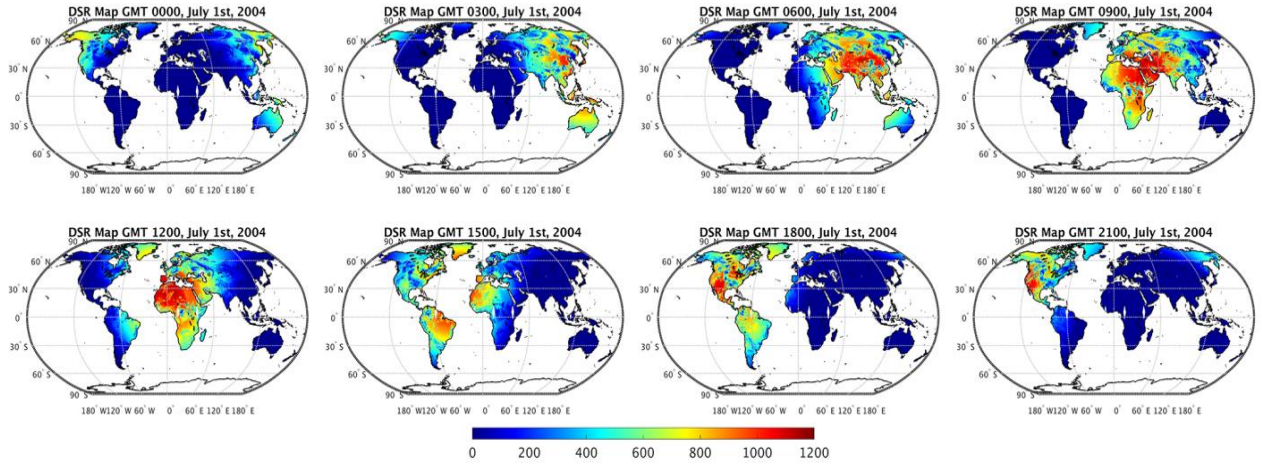
Insolation products	Spatial resolution	Temporal resolution	Temporal range
ISCCP	280km	3-hour	1983-2008
GEWEX-SRB	1°	3-hour	1983-2007
CERES	1°	3-hour	1997-present

WMO requirements for surface downward shortwave radiation

	Uncertainty goal (Wm^{-2})	Uncertainty threshold (Wm^{-2})	Horizontal resolution goal (km)	Horizontal resolution Threshold (km)
Global NWP	1	20	10	100
Agricultural Meteorology	N/A	N/A	1	20
Climate-AOPC	5	10	25	100

MODIS DSR and PAR products

- C6 products released in Sept. 2017
- Terra and Aqua MODIS combined products
- Two products
  - MCD18A1: daily 3-hourly global 5km DSR tile
  - MCD18A2: daily 3-hourly global 5km PAR tile
- Two groups of data sets
  - Instantaneous diffuse/direct/total values at MODIS overpass time
  - Total DSR/PAR at 3-hourly intervals

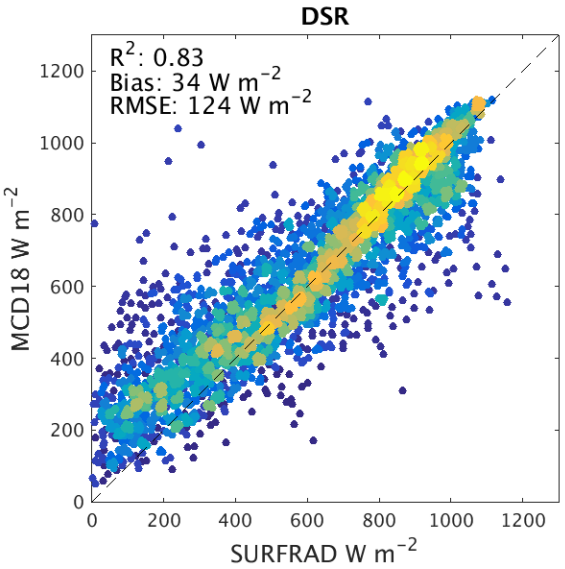


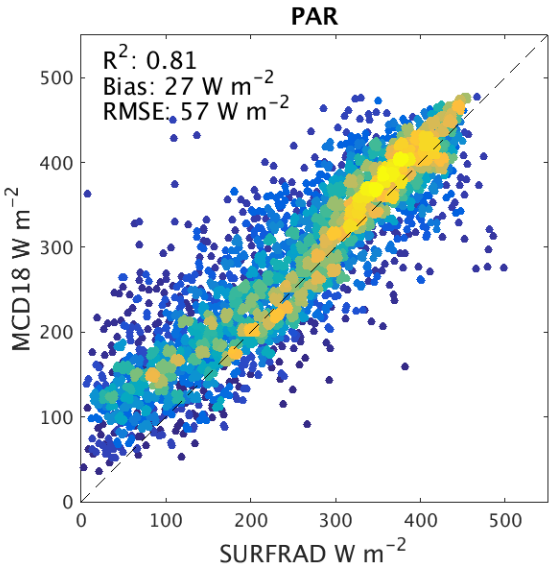
Example of C6 MCD18A1 : global maps of 3-hourly DSR on July 1 2004 from Terra and Aqua MODIS.

The figure illustrates the incident solar radiation over land surfaces shifting from the East to the West.

Status of MCD18 C6 products

- MCD18A1 and MCD18A2 products from 2000-2011 were generated.
- Labelled as beta maturity level
- Overestimation was observed due to programming errors:
  - Failure in reading MERRA2 water vapor data
  - Error in dealing with solar zenith angle

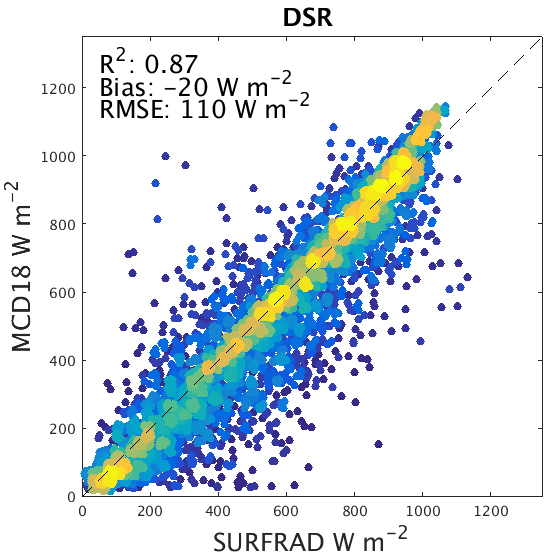


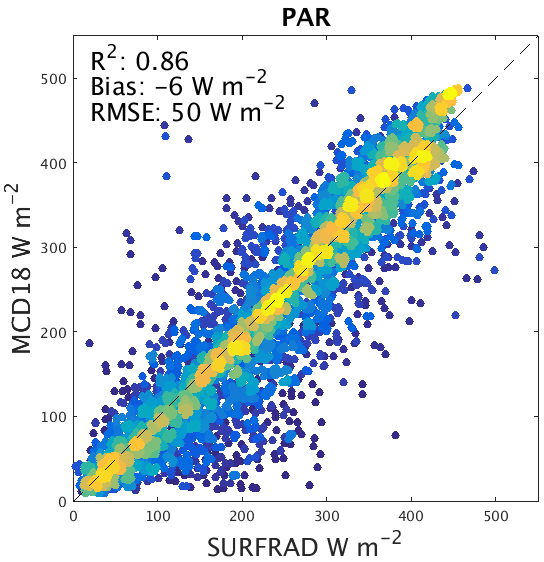


Validation results of the MCD18A1 and MCD18A2 C6 products with SURFRAD measurements. The data of the entire year of 2004 at the seven SURFRAD measurements are used.

Refinements in MCD18 C61

- C61 codes fixed the known programming errors.
- Spatial resolution was improved from 5km to 1km.
- Added new 0.05 degree CMG products of DSR (MCD18C1) and PAR (MCD18C2).
- Improved LUT with better representation of clouds.
- C61 codes have been delivered, integrated and tested.



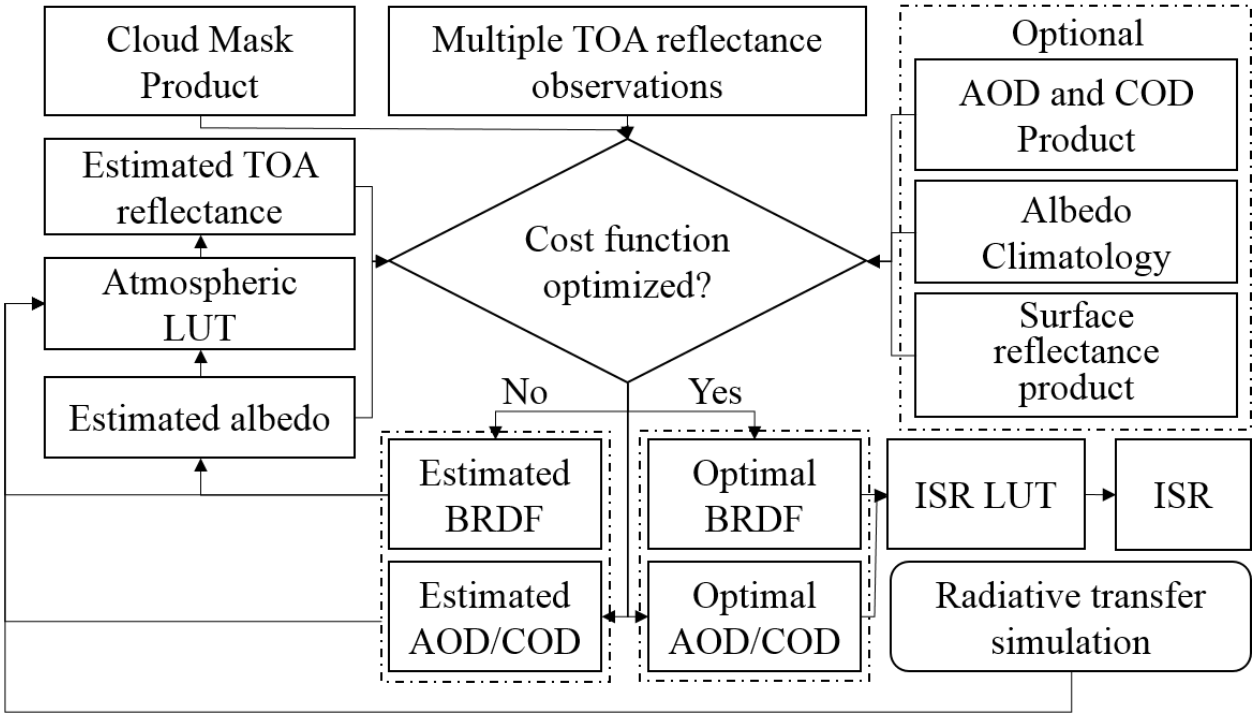


Comparison results of the DSR and PAR data generated from the C61 software codes with the SURFRAD measurements.

The issue of overestimation was fixed.

Algorithm improvements

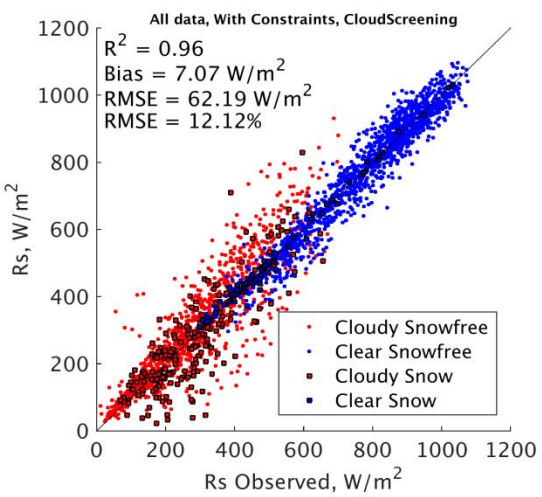
- Shortcomings of current algorithm
  - limited spectral information
  - surface reflectance needed
- Optimization-based approach was developed
  - Simultaneously retrieve atmospheric and surface parameters

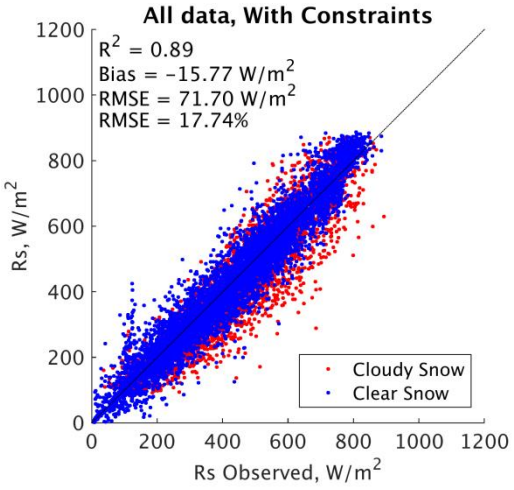


Flowchart of the optimization-based retrieval algorithm for DSR and PAR

Optimization-based approach

- Modelling radiative transfer with libRadtran
- Surface BRDF considered
- Flexible with optional inputs of atmospheric and surface parameters as constraints

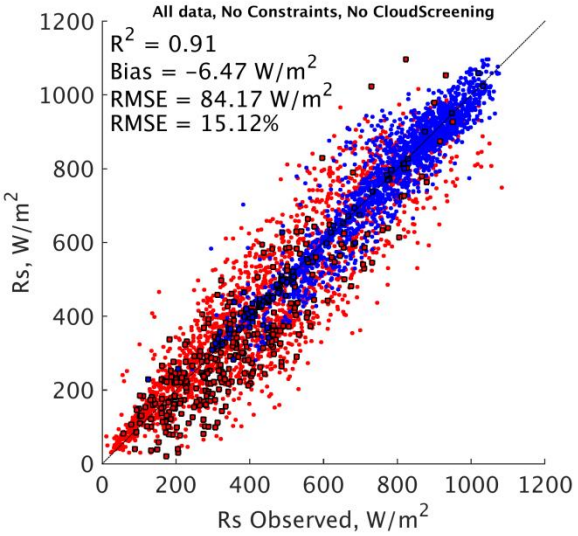


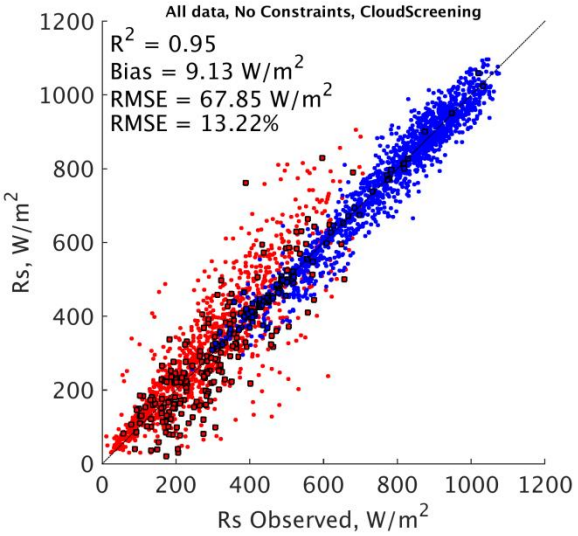


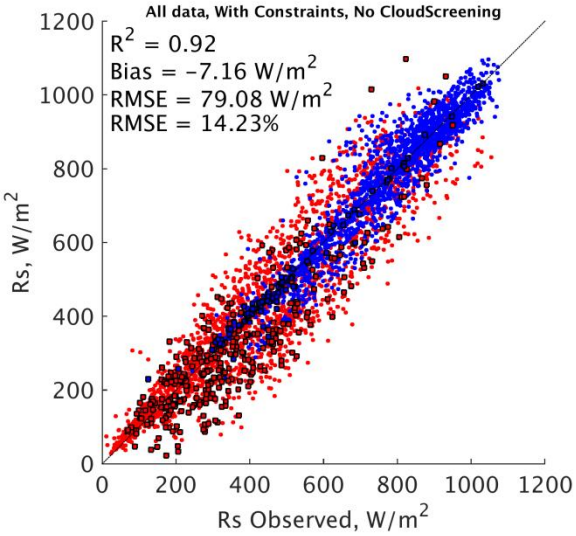
Validation results of MODIS DSR retrieved with the optimization-based approach using field measurements in 2013 at SURFRAD (left) and GC-net (right) sites.

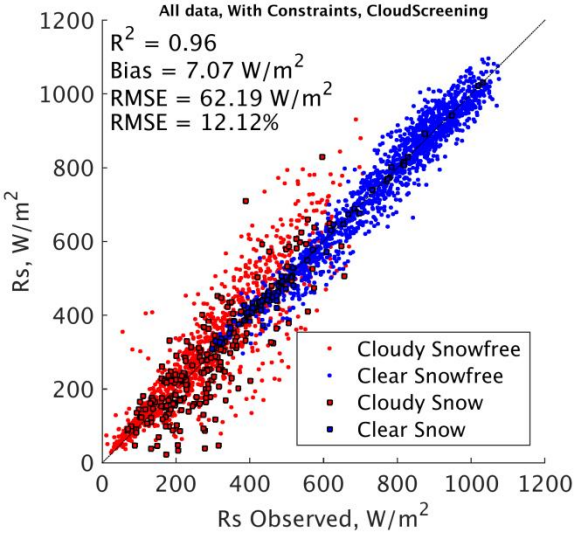
Zhang, Y., He, T., Liang, S., Wang, D., & Yu, Y. (2018). Estimation of all-sky instantaneous surface incident shortwave radiation from Moderate Resolution Imaging Spectroradiometer data using optimization method. *Remote Sensing of Environment*, 209, 468-479

Cloud screening and constraints





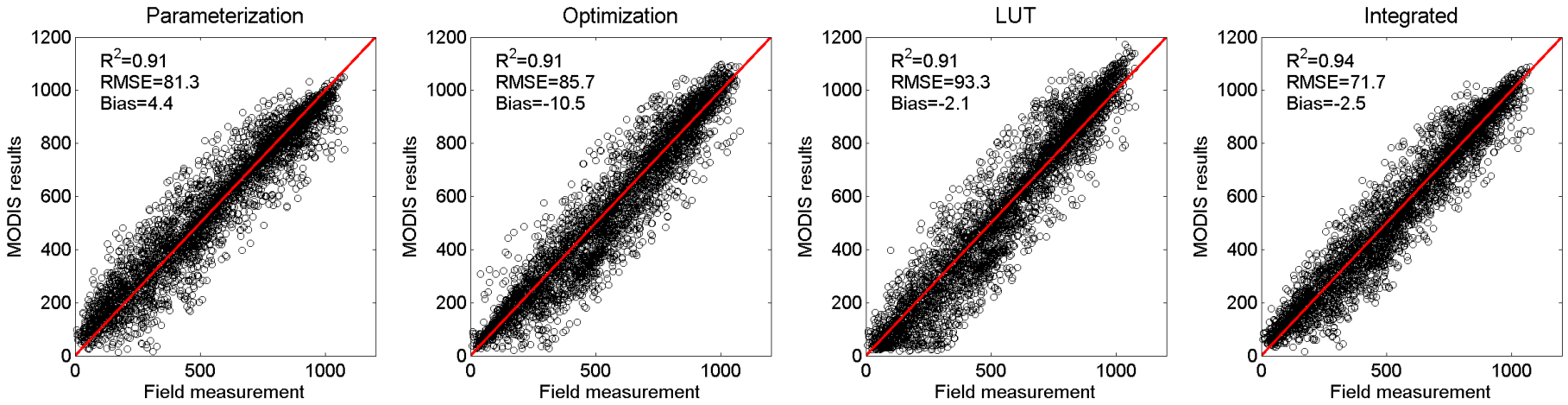




Data integration

- Ideal way to take advantage of multisource information
- Combine existing MCD18 products with estimates from alternative approaches
- Mature optimal interpolation based approach

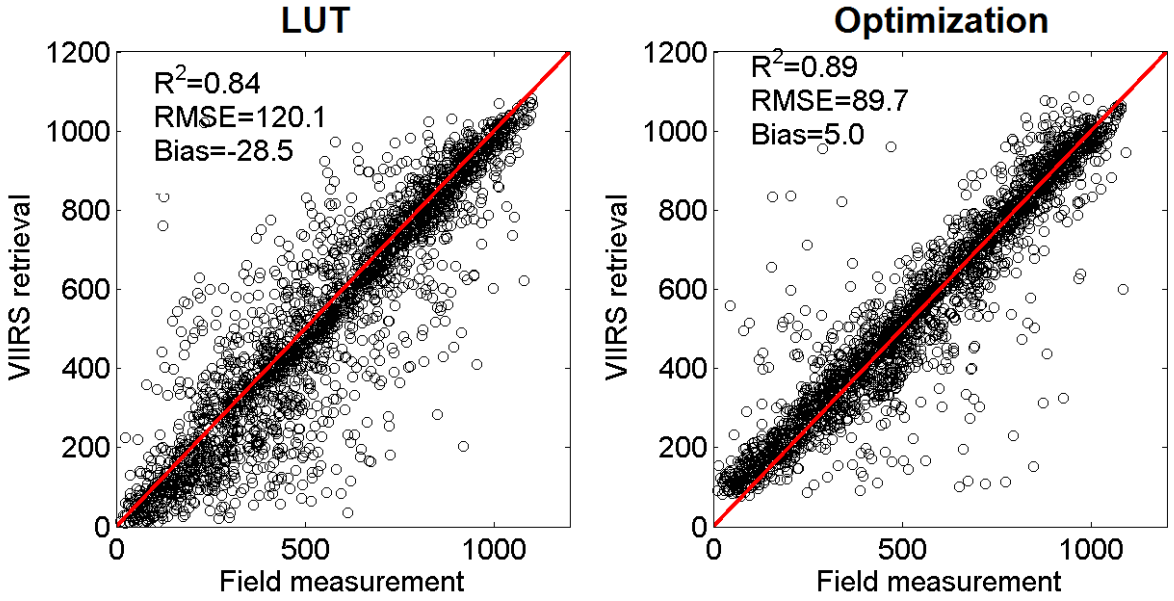
$$R_I = \frac{\sigma_O^2\sigma_L^2 R_P + \sigma_P^2\sigma_L^2 R_O + \sigma_O^2\sigma_P^2 R_L}{\sigma_O^2\sigma_L^2 + \sigma_P^2\sigma_L^2 + \sigma_O^2\sigma_P^2}$$



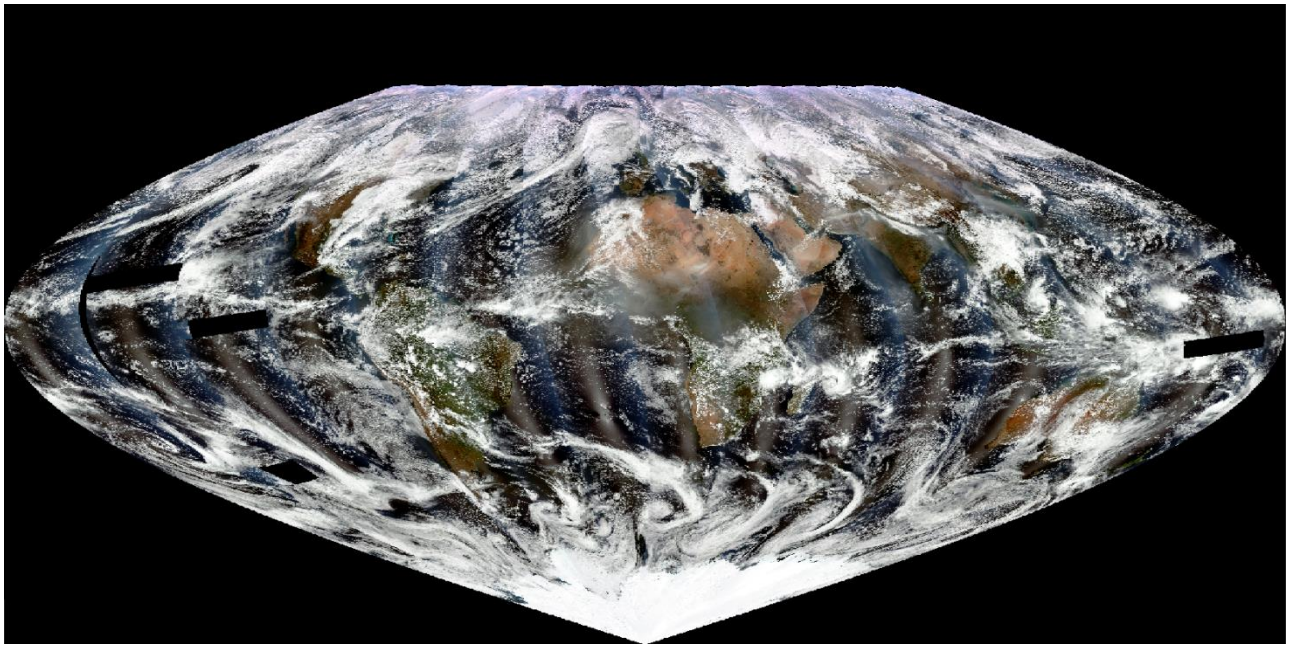
Validation results of the integrated DSR data from the parameterization, optimization and LUT methods.

Study on Suomi NPP VIIRS data

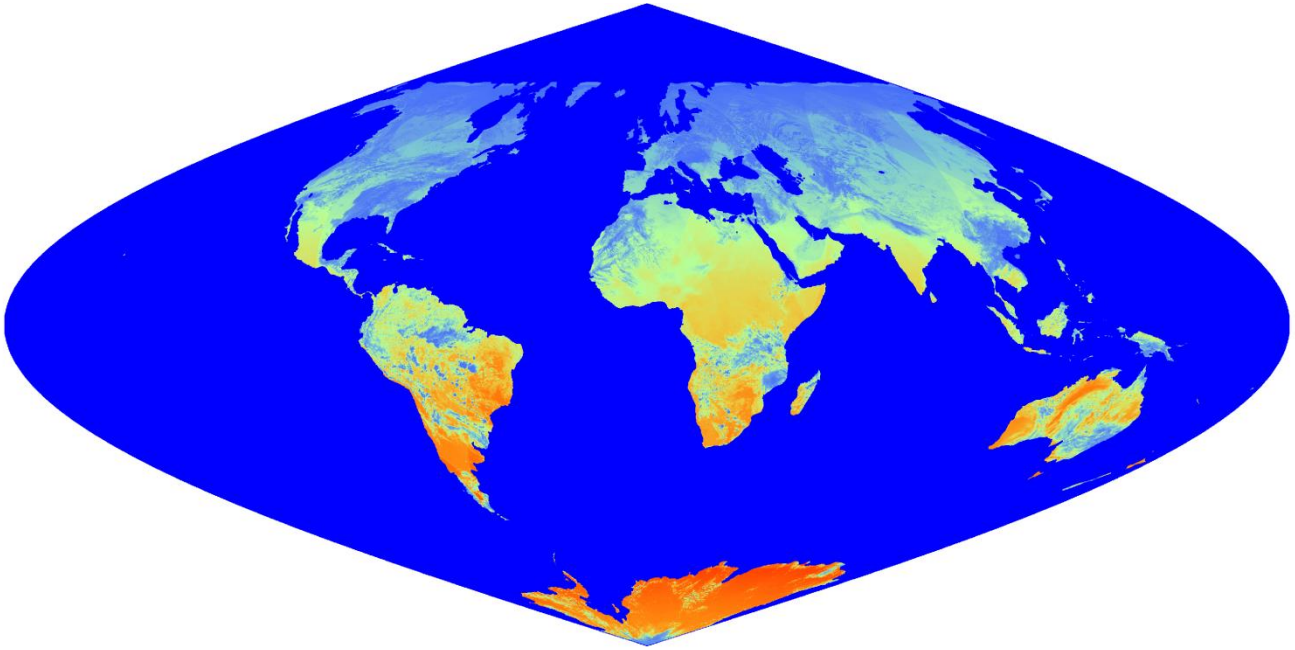
- Benefits of VIIRS data
  - Serve as additional data sources to improve accuracy of 3-hourly interpolation.
  - Replace MODIS products when MODIS is gone.
- Both the LUT and optimization approaches have been successfully adapted to VIIRS data.
- Scientific software codes to generate VIIRS DSR and PAR products data have been developed and tested.



Validating VIIRS DSR estimated from both the LUT and optimization approaches using the SURFRAD measurements in 2013.



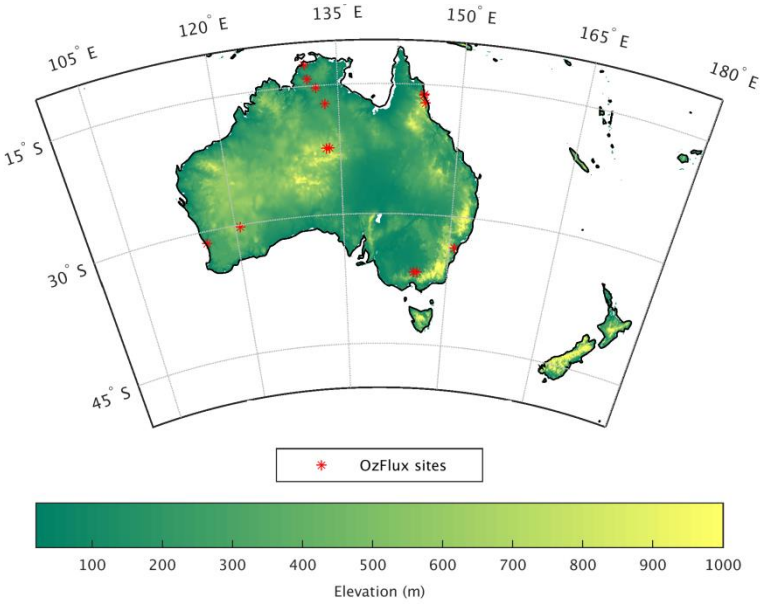
Global color-composite map on Jan. 11 2015 from Suomi NPP/VIIRS data.

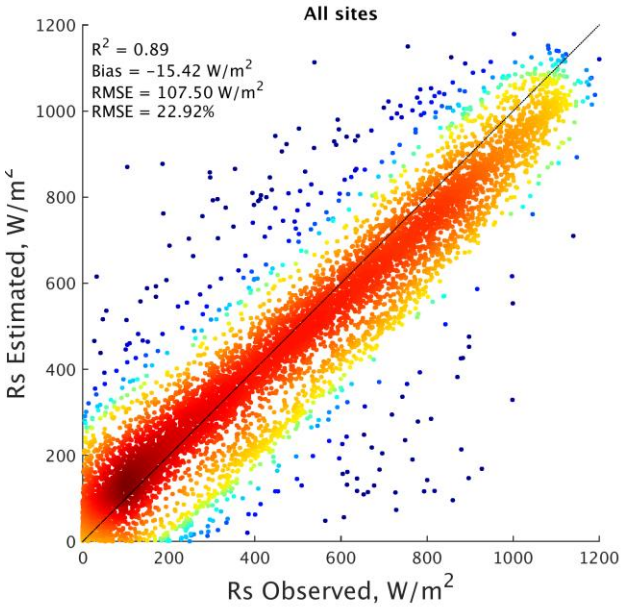


Daily mean DSR map generated from VIIRS.

Incorporation of geostationary data

- New generation geostationary data
  - GOES-R/ABI
  - Himawari-8/AHI
- Improved spatial/spectral/temporal resolutions





In situ data collected at OzFlux stations (left) are used to validate AHI retrievals of DSR (right)

Summary

- MCD18 C6 products were released in 2017.
- Beta maturity level was assigned due to existence of programming errors.
- C61 products fix the errors and have several improvements.
- C61 software has been delivered, integrated and tested.
- Scientific codes to generate VIIRS DSR and PAR are ready.
- Active researches are underway to continue refining algorithms and improving retrievals.