Evaluation of Satellite Albedo Products over BSRN Sites

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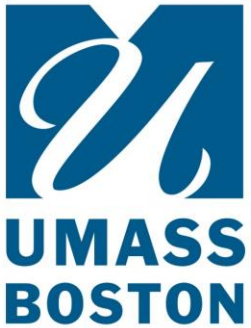
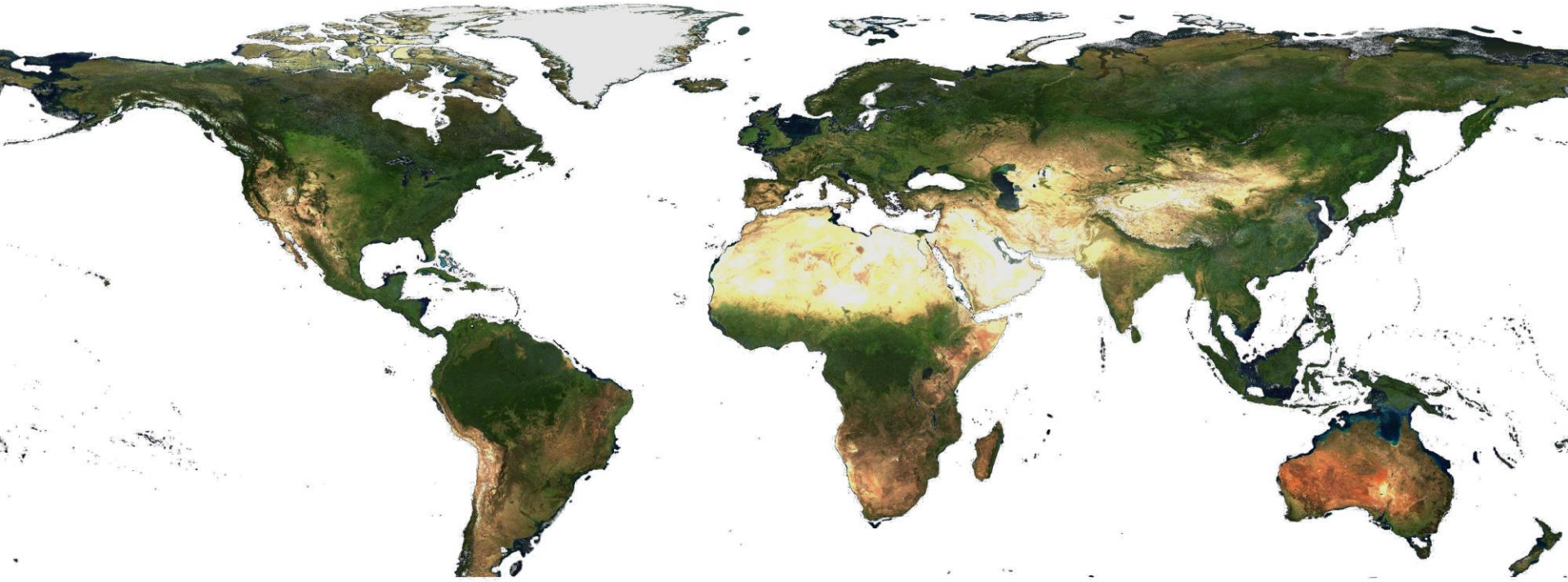


Albedo Validation Protocol

The CEOS WGCV Land Product Validation (LPV) subgroup is designated to play a key coordination role, and to lend the expertise required to validate global surface albedo measurements as identified in GCOS-138.



Current Satellite Albedo Products

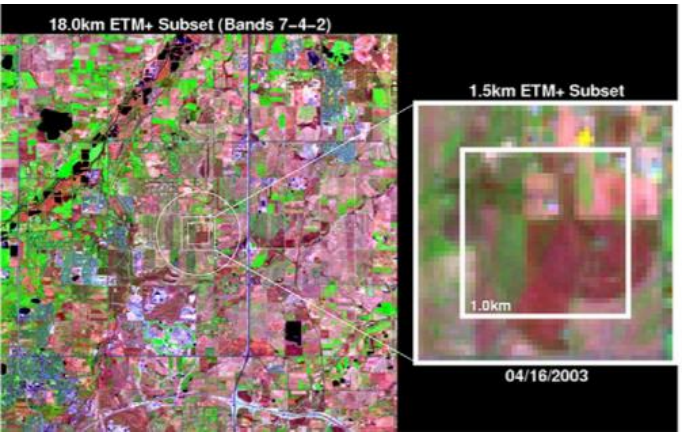
Product	Temporal Coverage	Spatial Scale	Temporal Scale
MERIS/SPOT-VGT	1998-2011	0.05deg or 0.5deg	8-day
AVHRR	1982-2015	0.25deg	Monthly, pentad (5-day)
MODIS	2000 - present	0.5km, 0.05 deg, 30arc sec	Daily
VEGETATION	1999-2013	1 km	10-day
GLASS (MODIS,AVHRR)	1981-2010	1 km, 0.05deg	8-day
MISR	2000 - present	1.1 km, 0.5 deg	Day, Mon, Qtr, Annual (global repeat 9 days)
VIIRS (NOAA)	2011-present	1km	Daily
CERES	2000 - 2016	20km, 1 deg	Instantaneous, 3hrs, monthly
MSG SEVERI	2005 - present	3 km (nadir)	Daily, 10-day
POLDER	1996-97(P1)	6 km	10-day
Meteosat	1981-2011	3 km (nadir)	10-day

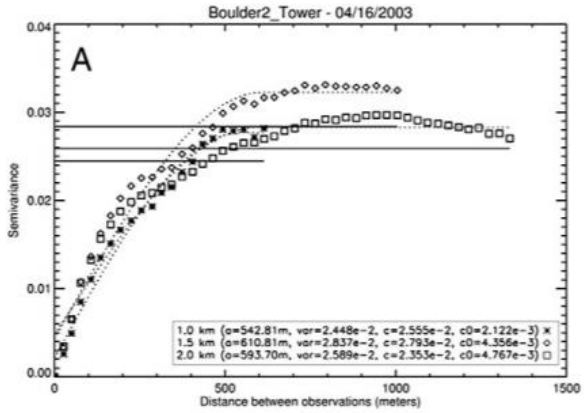
Surface Albedo Validation Strategy

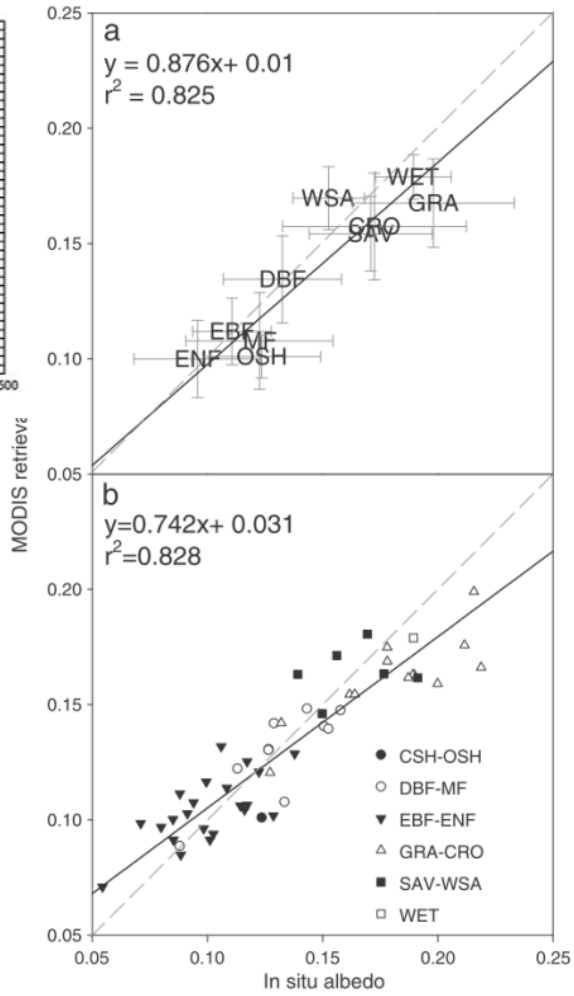
- ***In-situ* tower-based validation**
- **Satellite products inter-comparison**
- **Upscaling high spatial resolution airborne/spaceborne albedo**

Stage	Description
Stage 1 Validation	Product accuracy is assessed from **a small (typically < 30) set of locations and time periods** by comparison with in-situ or other suitable reference data.
Stage 2 Validation	Product accuracy is estimated over a **significant set of locations and time periods** by comparison with reference in situ or other suitable reference data. The **spatial and temporal consistency** of the product and with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.
Stage 3 Validation	**Uncertainties in the product and its associated structure are well quantified** from comparison with reference in situ or other suitable reference data. Uncertainties are characterised in a statistically robust way over multiple locations and time periods representing **global conditions**. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.
Stage 4 Validation	Validation results for stage 3 **are systematically updated when new product versions are released and as the time-series** expands.

In-situ tower-based validation



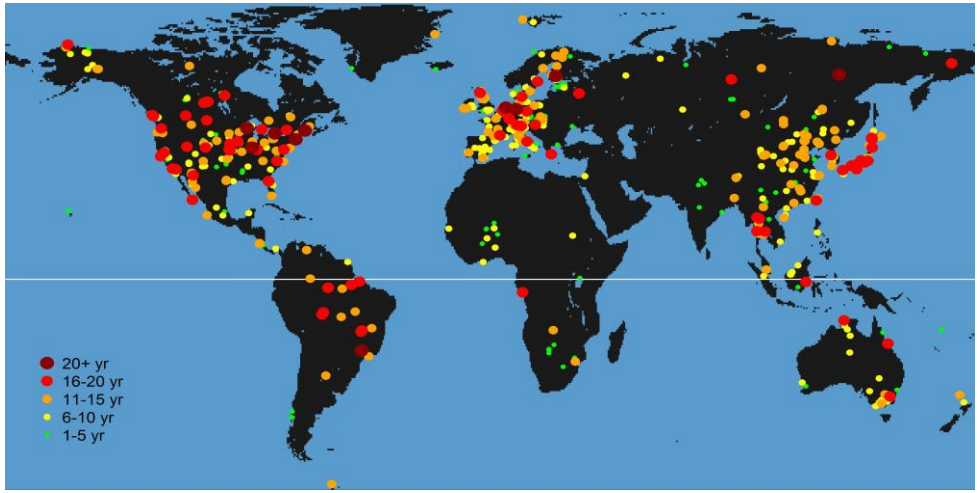


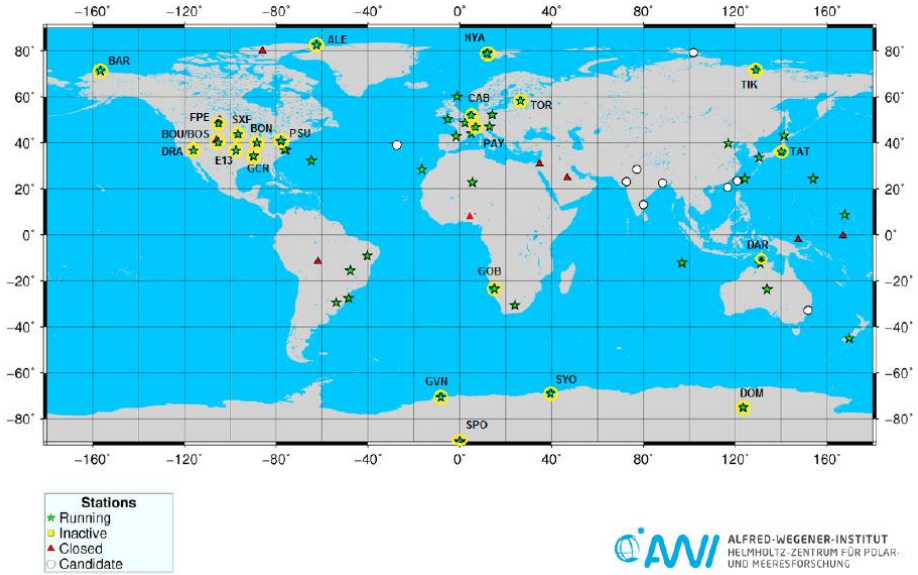


MODIS albedo retrievals vs. in-situ observations grouped by plant functional types (PFTs) (a), and by individual sites classified by PFT (b).

Cescatti et al. RSE, 2012

In-situ Reference Sites





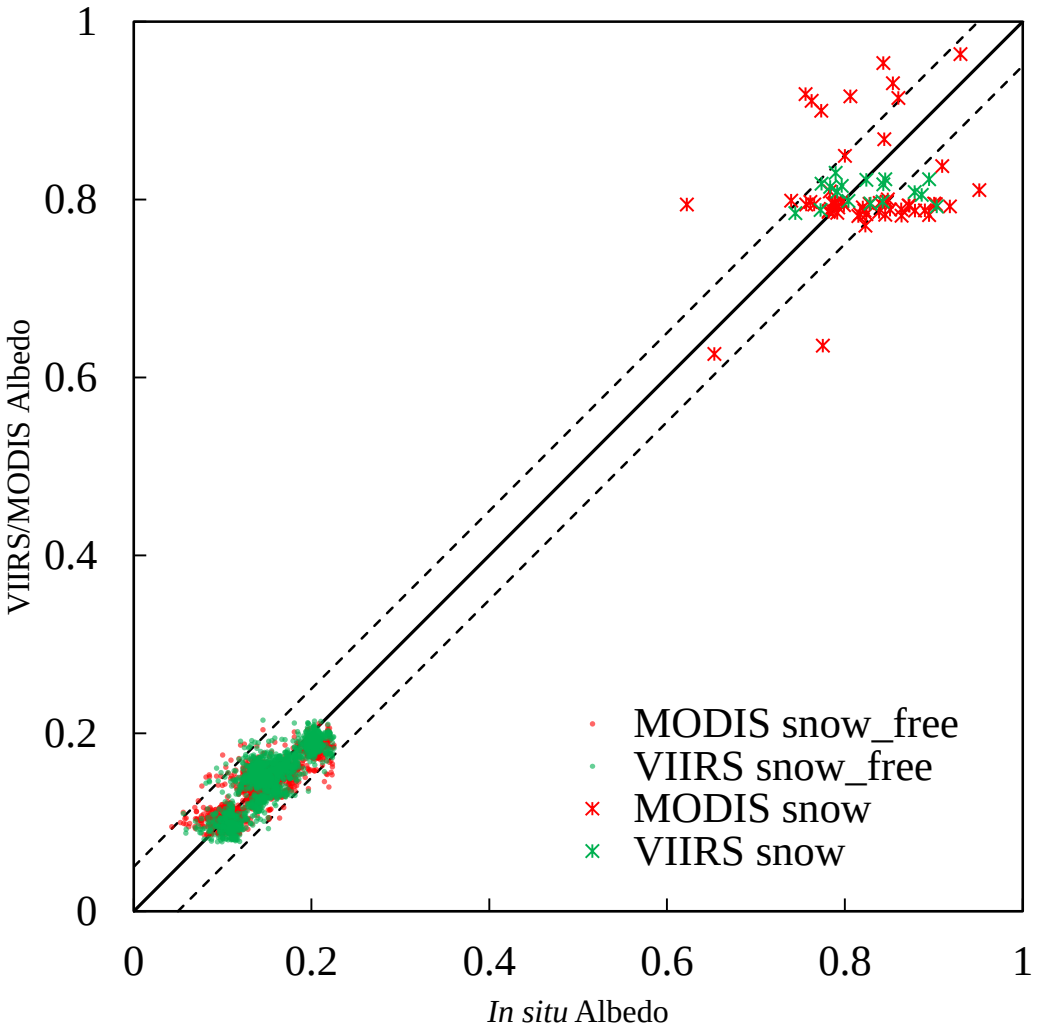
FLUXNET 2015 sites (http://fluxnet.fluxdata.org/about/regional-networks/)

CarboeuropeIP, AmeriFlux, Fluxnet-Canada, LBA, Asiaflux, Chinaflux, USCCC, Ozflux, Carboafrica, Koflux, NECC, TCOS-Siberia and Afriflux

BSRN sites

Network	Reference / Remark
FLUXNET	http://fluxnet.ornl.gov/
BSRN	http://www.bsrn.awi.de/
NEON	http://www.neonscience.org/
GC-Net	http://cires1.colorado.edu/steffen/gcnet/

MODIS/VIIRS derived blue-sky albedo against *in situ* blue-sky albedo measurements

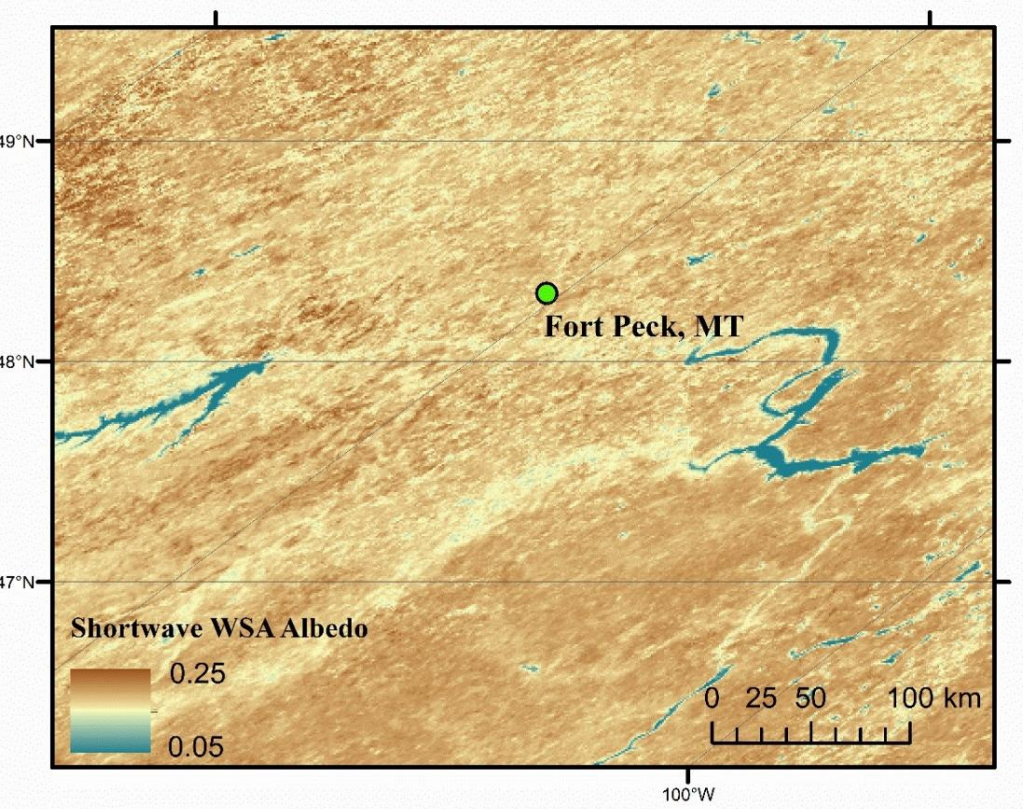


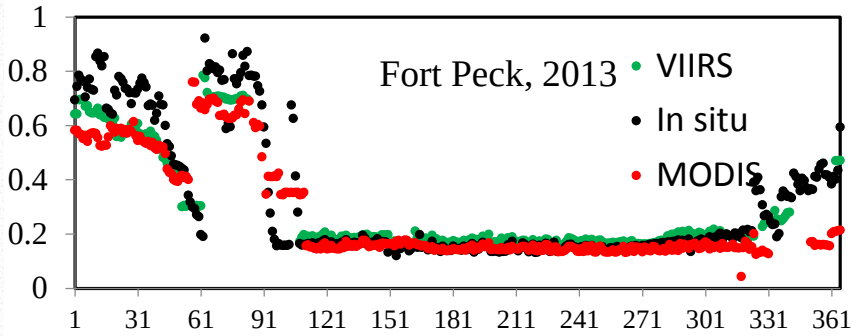
The RMSE of the 1km VIIRS and MODIS albedos as compared to the *in situ* measurement at 9 tower sites in 2015.

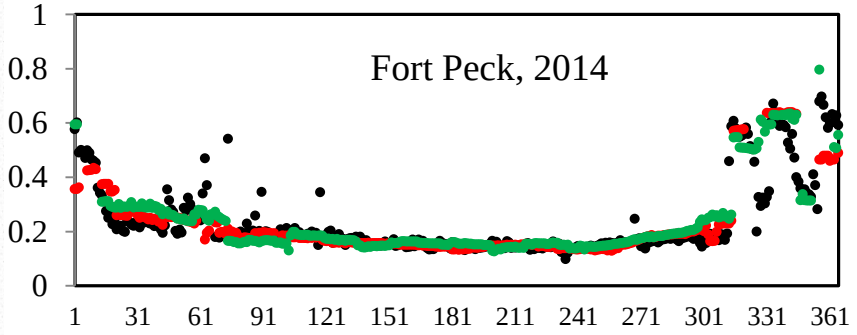
	snow-free		
	num.obs	RMSE	Bias
VIIRS	1734	0.0195	-0.0034
MODIS	2049	0.0195	-0.0038
	snow		
	num.obs	RMSE	Bias
VIIRS	17	0.0488	-0.0156
MODIS	53	0.0760	-0.0121

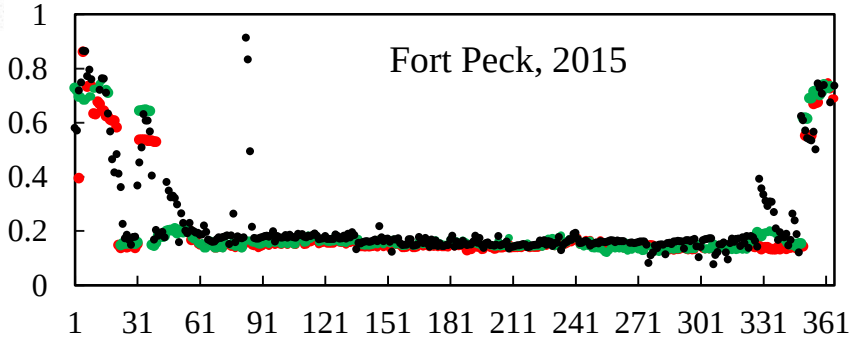
Liu, et.al., 2017

MODIS/VIIRS Albedo at Fort Peck SURFRAD tower site 2013-2015



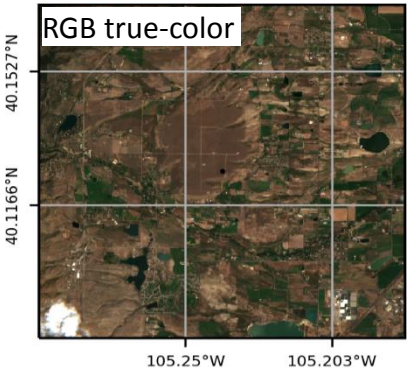




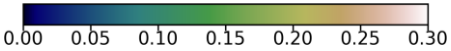


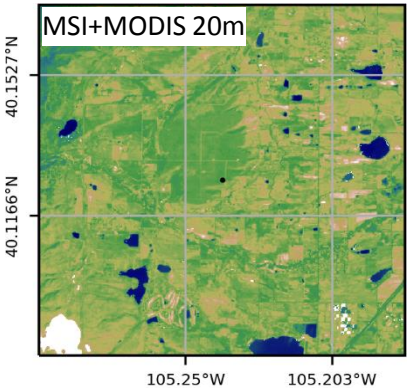
Suomi-NPP VIIRS Daily Shortwave Albedo is typically evaluated at spatially representative field sites (such as this Fort Peck tower site in the rangelands of Montana) showing the consistency of the VIIRS values in comparison with heritage MODIS results and *insitu* data.

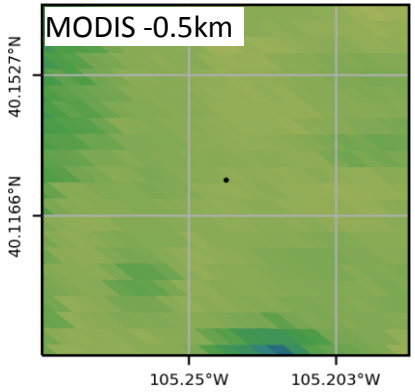
Sentinel-2A MSI albedo at Table Mountain SURFRAD site

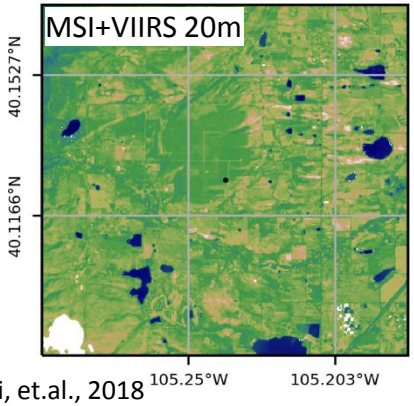


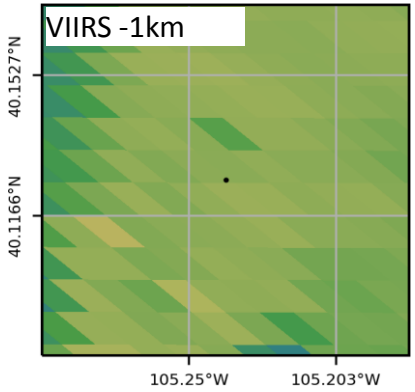
Snow-free subset of Sentinel-2A MSI albedo: 2016-08-25

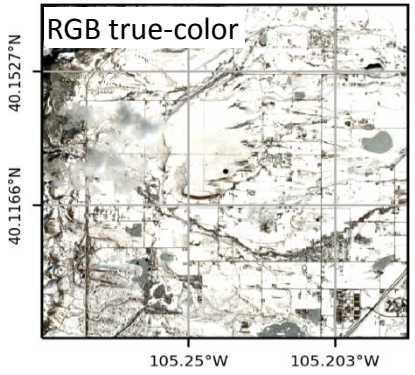




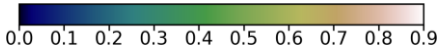


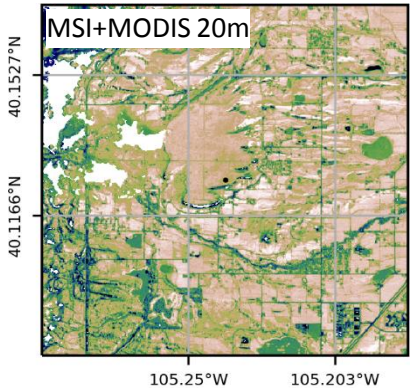


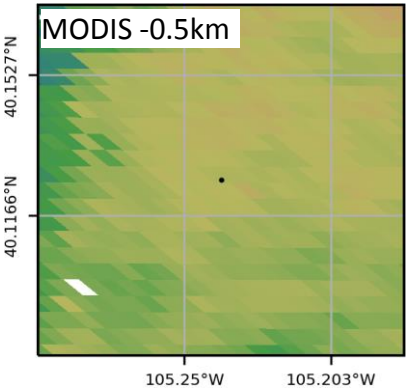


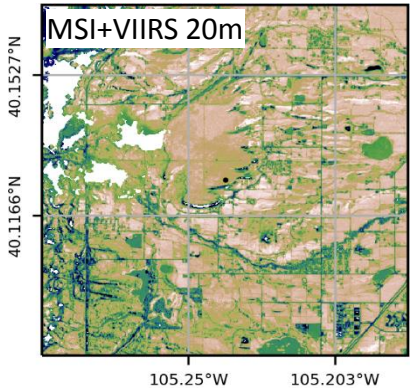


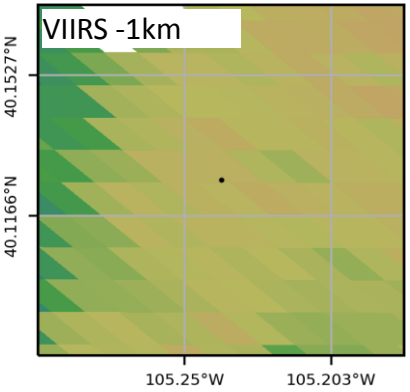
Snow-covered subset of Sentinel-2A MSI albedo: 2016-02-07







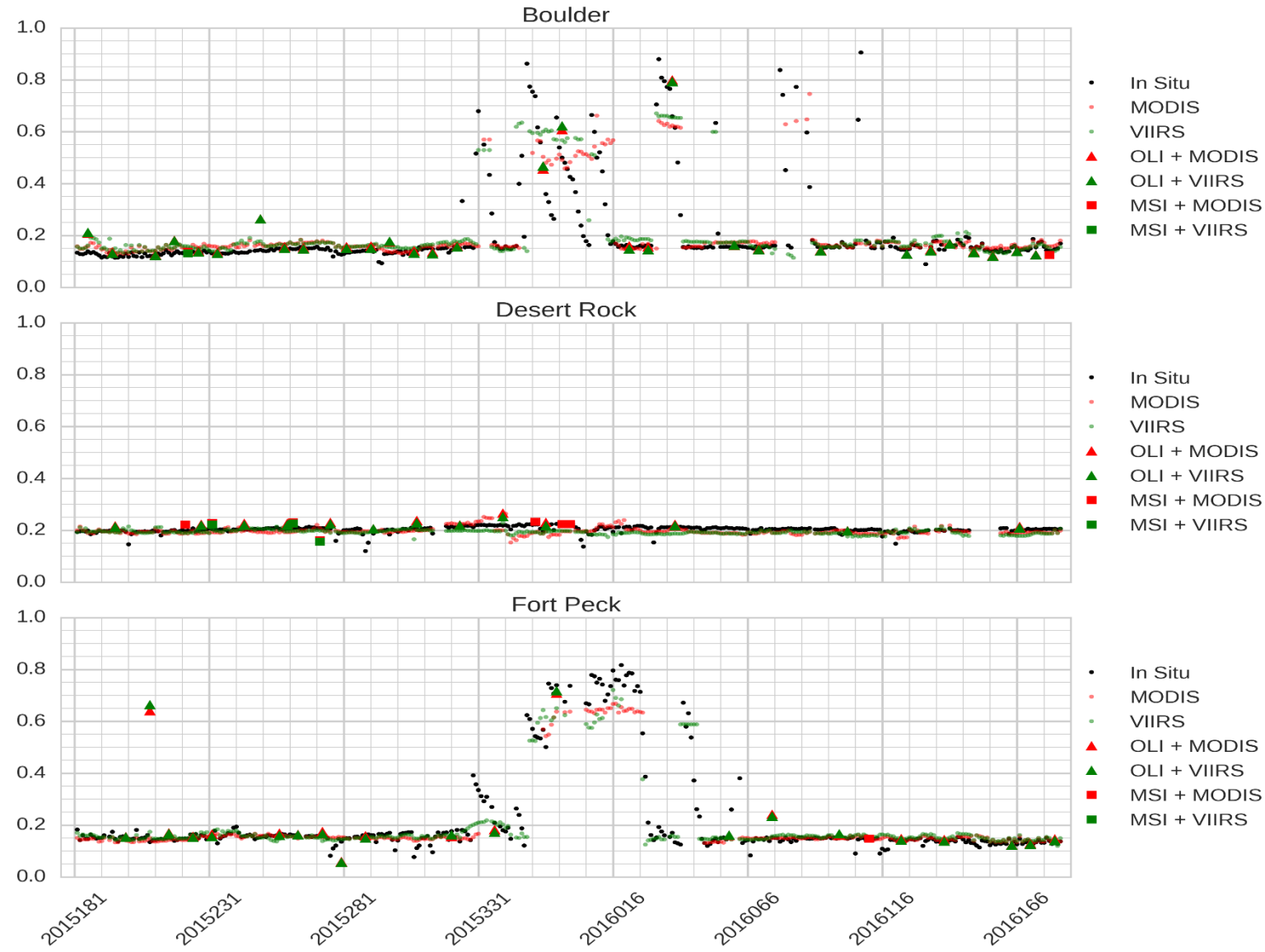




Li, et.al., 2018

Landsat/Sentinel Albedo Validation

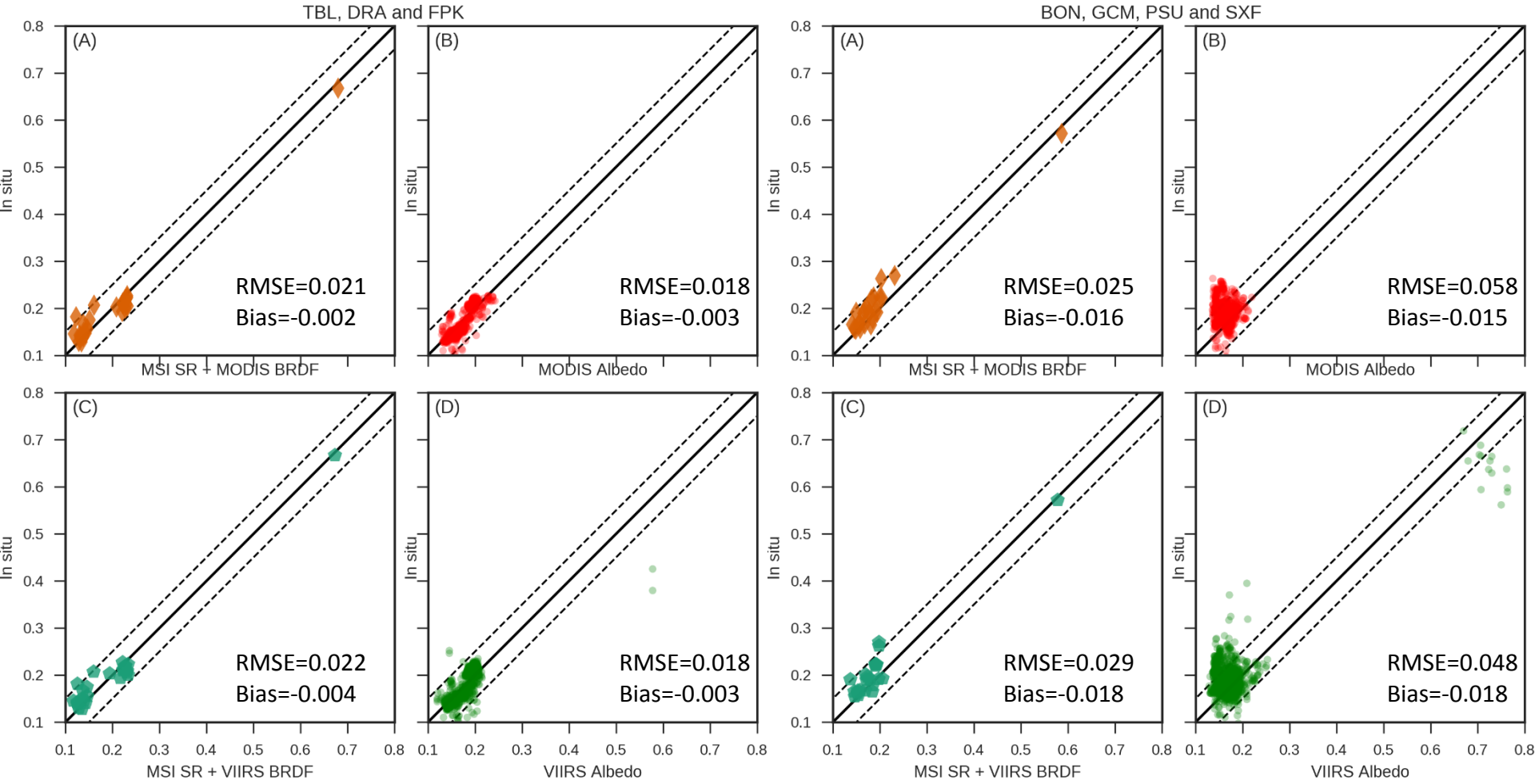
Three spatially representative sites, Snow Included, July 2015 – July 2016



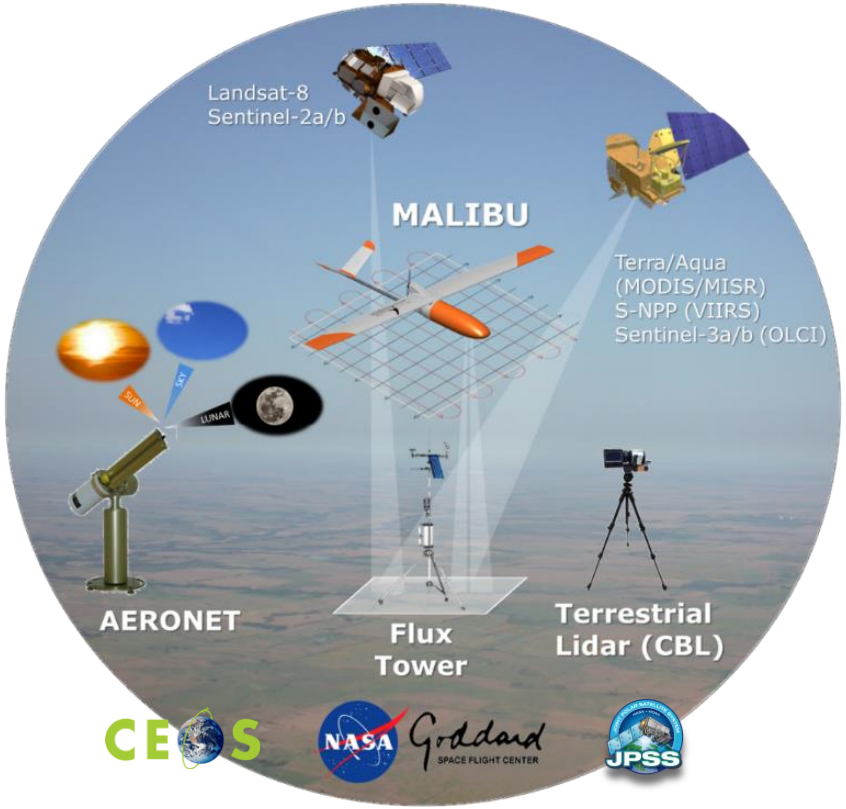
Sentinel 2A blue-sky albedo against *in situ* blue-sky albedo measurements

SURFRAD sites *representative* for coarse-resolution albedo products

SURFRAD sites *not representative* for coarse-resolution albedo products



Multi AngLe Imaging Bidirectional Reflectance Distribution Function sUAS (MALIBU)



https://viirsland.gsfc.nasa.gov/Campaigns.html

Summary:

Joint NASA GSFC 618/619 effort to develop multi-angular reference datasets for the assessment of BOA reflectance-based products (e.g., BRDF, albedo, NBAR, VI, PRI, LAI/FPAR, snow cover, and phenology metrics).

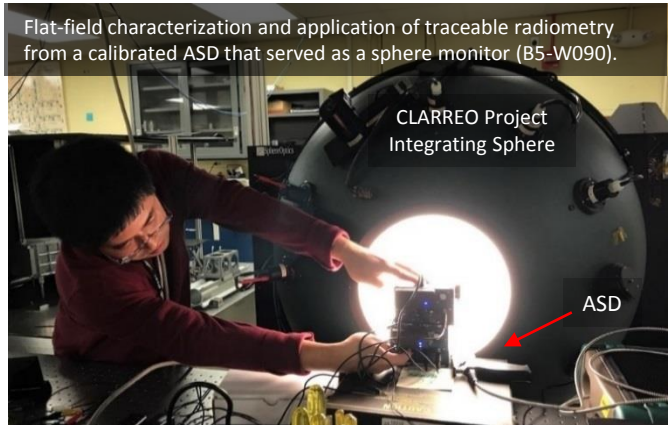
MALIBU Deployment

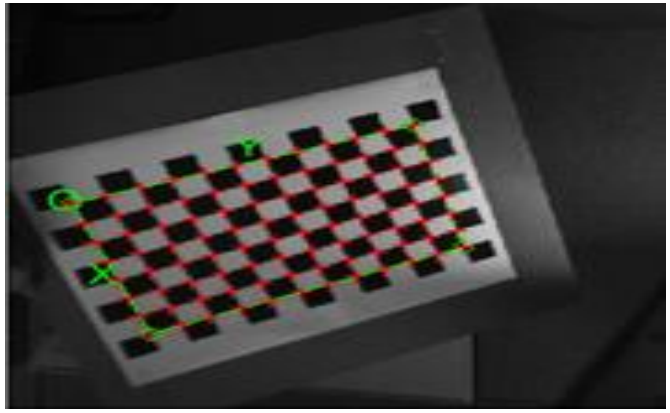
Benefits:

A cost effective ($300 × Flight Hour), exempted (FAA-S.333 & TCAN) platform, that follows CEOS-WGCV good practice protocols.

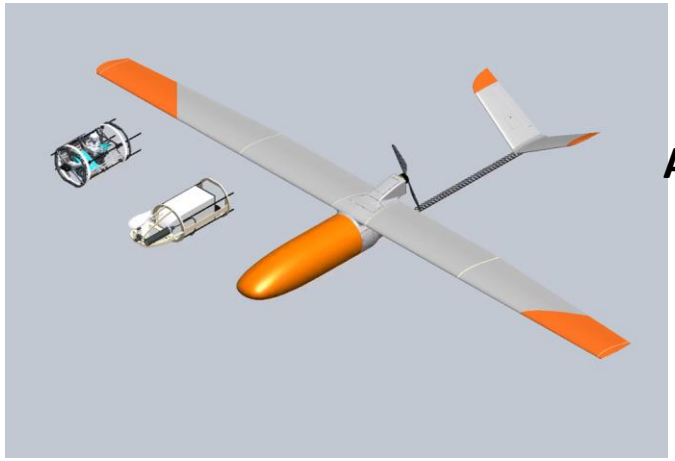
MALIBU's 'abilitys' (Key Performance Characteristics)

Traceability





Mobility



Adaptability

MALIBU Payload

Multispectral 2D-array CMOS cameras

Dimensions: 87H * 131L * 78W (mm); Weight: 1.4 kg (700g / camera)

Spectral coverage

- Six channels: 442nm, 488nm, 531nm, 560nm, 650nm, 861nm
- FWHM ~25nm

Field of View (FOV)

- Frame size: 1280 * 1024 pixels
- FOV: 58.5°(per camera)

Pixel pitch

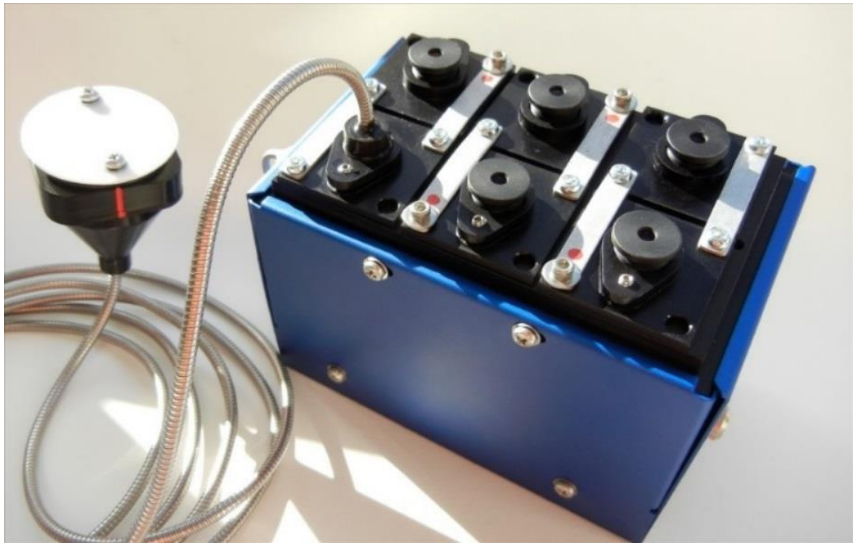
- 4.8 micron

GSD

- Un-aggregated: 6-20 cm

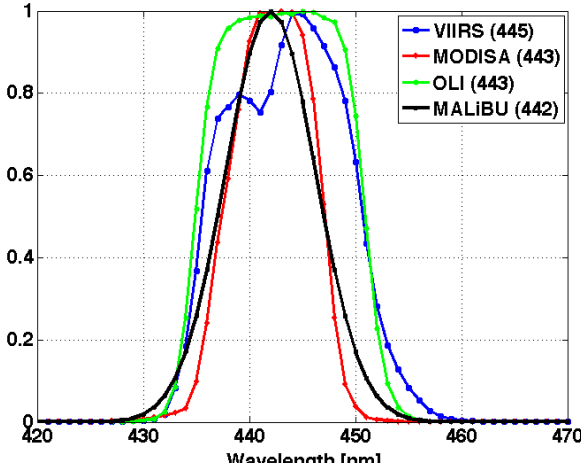
Signal to Noise: > 300

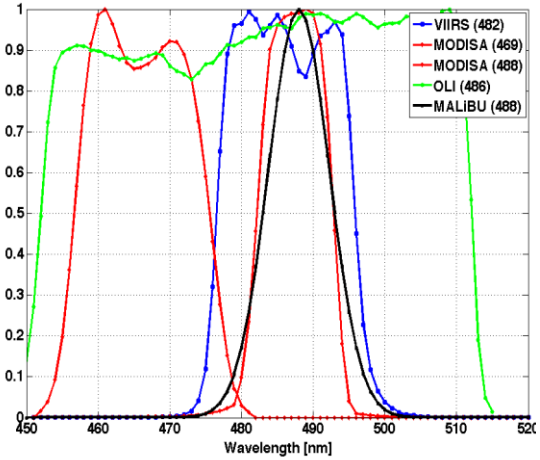
Radiometric uncertainty < 5%

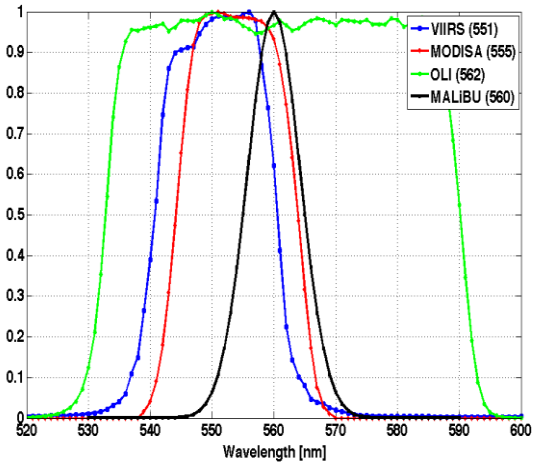


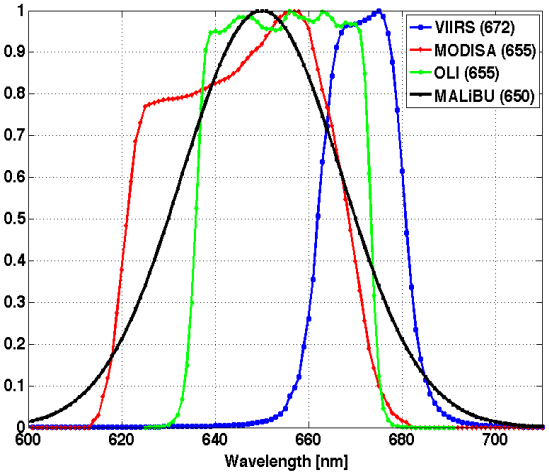
Tetracam's 6-channel camera with channel 1 attached to a fiber optics.

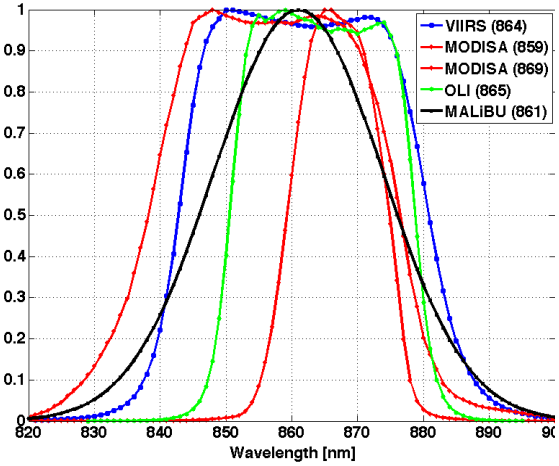
MALIBU Spectral Response Function

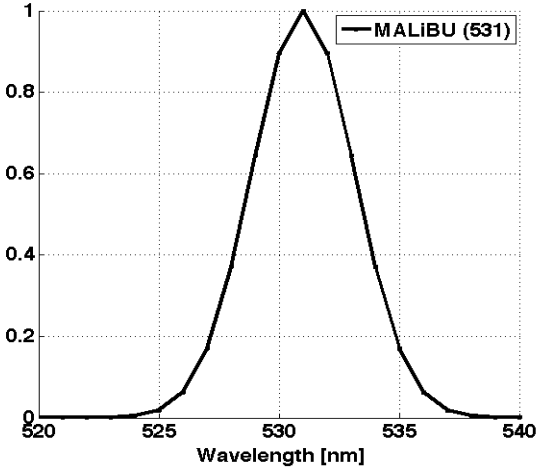












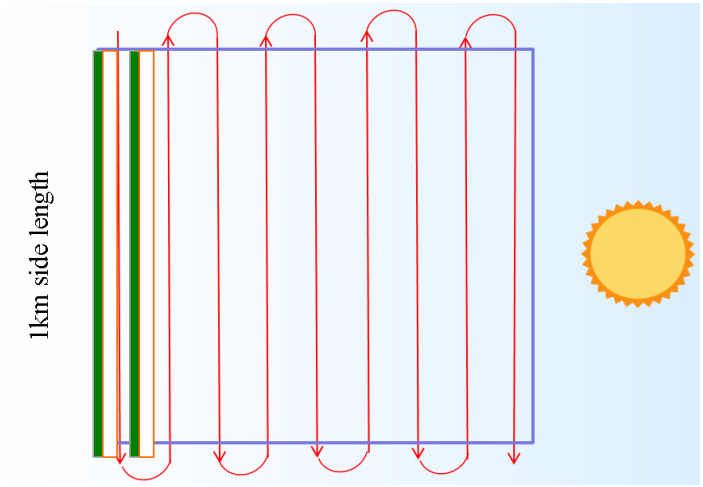
MALIBU Flight Plan

Assuming flying at 400 feet with 20 m/s speed

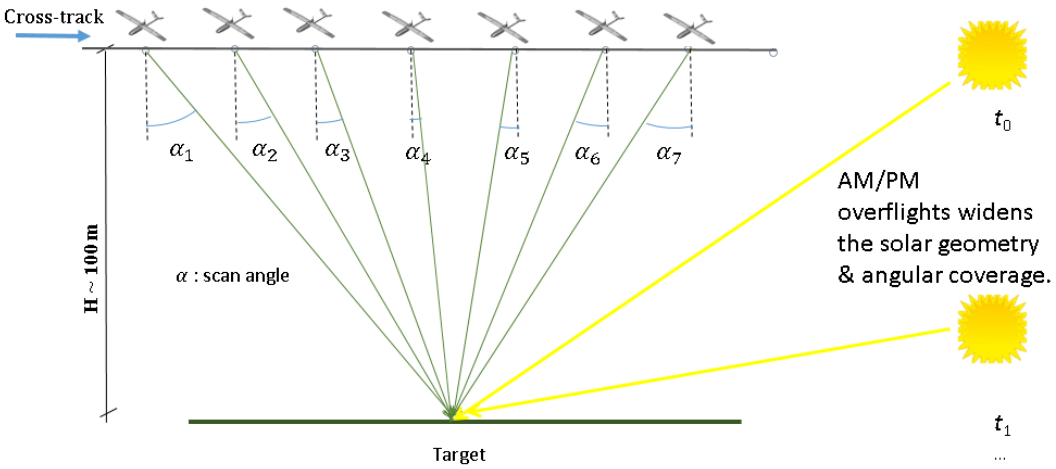
- ❑50 second / flight line (of length 1 km)

- ❑Inherent GSD
  - ~6 cm @ near-nadir
  - ~16 cm @ 55deg

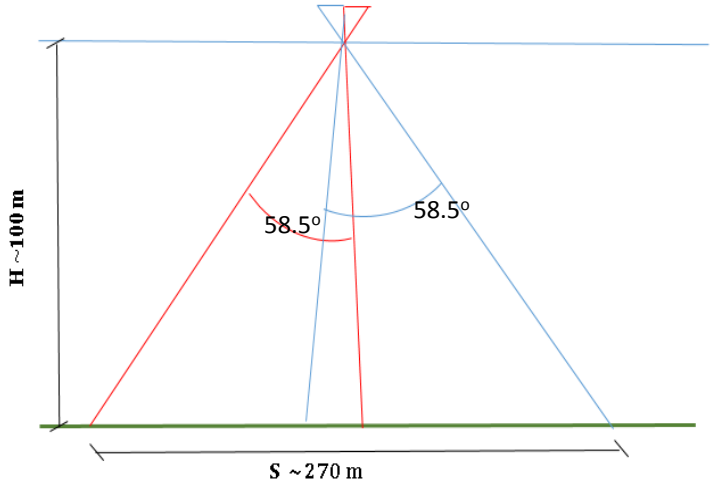
- ❑Total flight time ~30 min



Multi-angular observations



Dual Tetracam cameras



MALIBU Observation

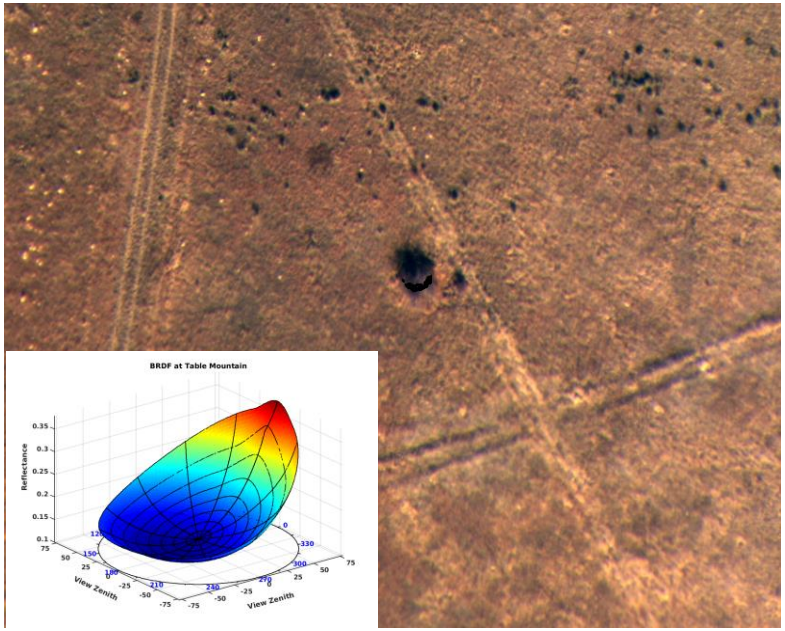
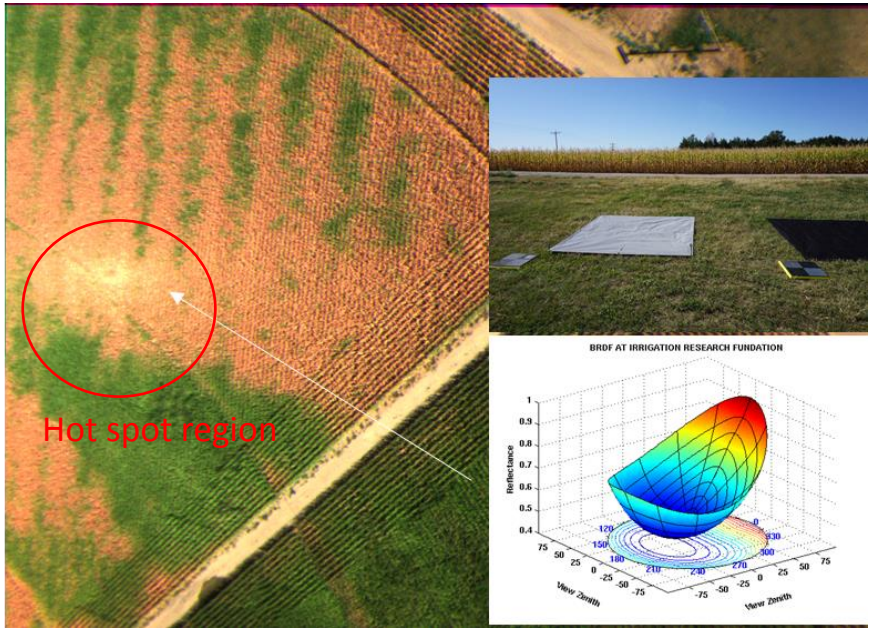


Table Mountain, CO, USA

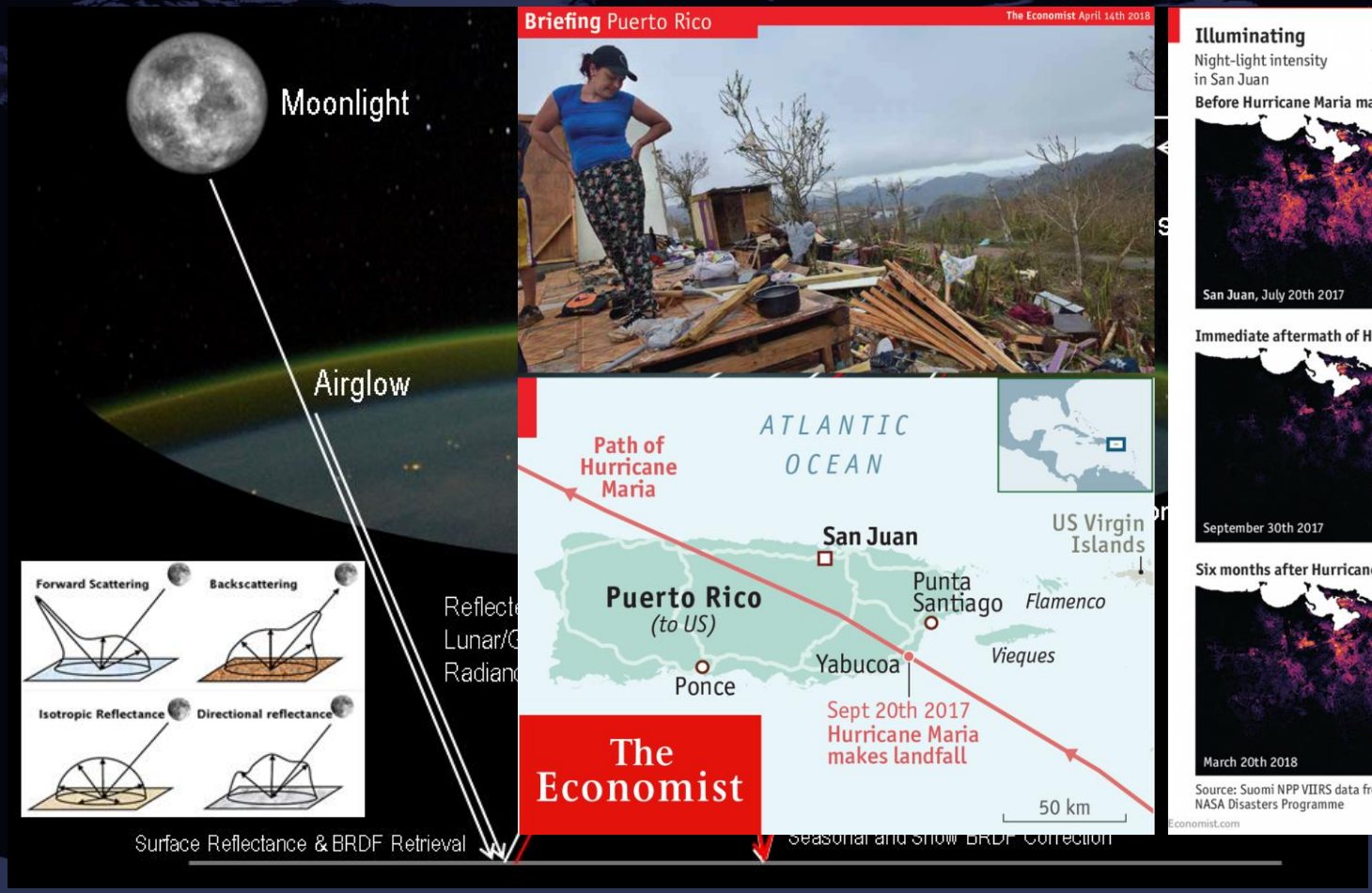


Yuma cropland, CO, USA

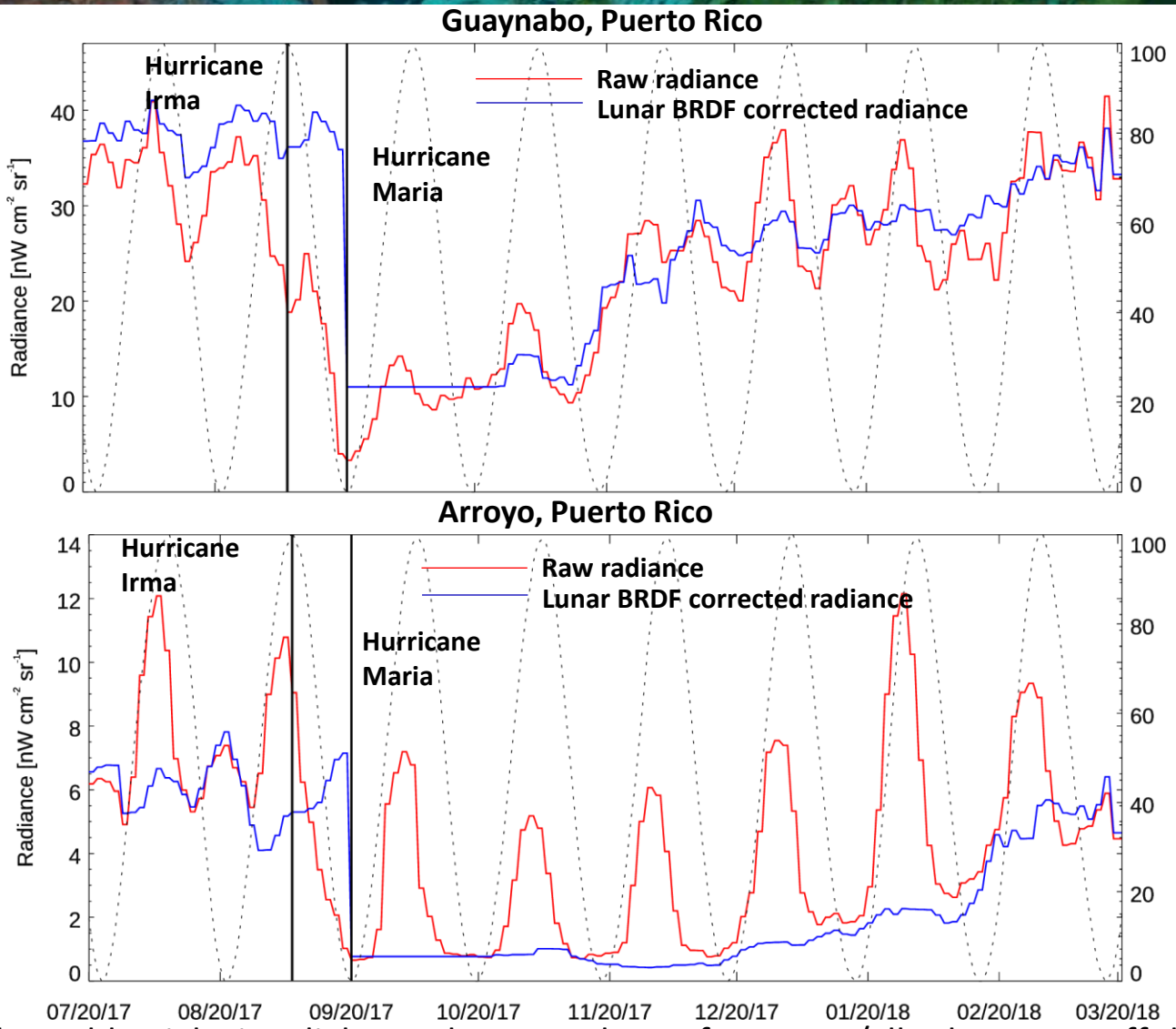
Albedo	Blue	Green	Red	Shortwave
MODIS	0.078	0.119	0.149	0.179
MALIBU	0.088	0.116	0.166	0.163
Flux tower				0.188

Surface Reflectance	Blue	Green	Red	NIR
Landsat8	0.077	0.111	0.131	0.282
MALIBU	0.081	0.115	0.131	0.271

NASA Black Marble Nighttime light product validation



NASA Black Marble Nighttime light product validation



- The Black Marble nighttime light product use the surface BRDF/albedo to turn off the moonlight
- MALIBU BRDF/albedo is validated using the *in-situ* tower albedo and then is used to evaluate VIIRS Black Marble products

Conclusion

- ❑ Satellite albedo products validation
- ❑ *In-situ* reference sites
- ❑ MALIBU deployment over different land types and snow
- ❑ Spectral albedo