UCSD SRAF

Solar irradiance forecasting using ground-based sky images

SIOG 236

06/07/2018

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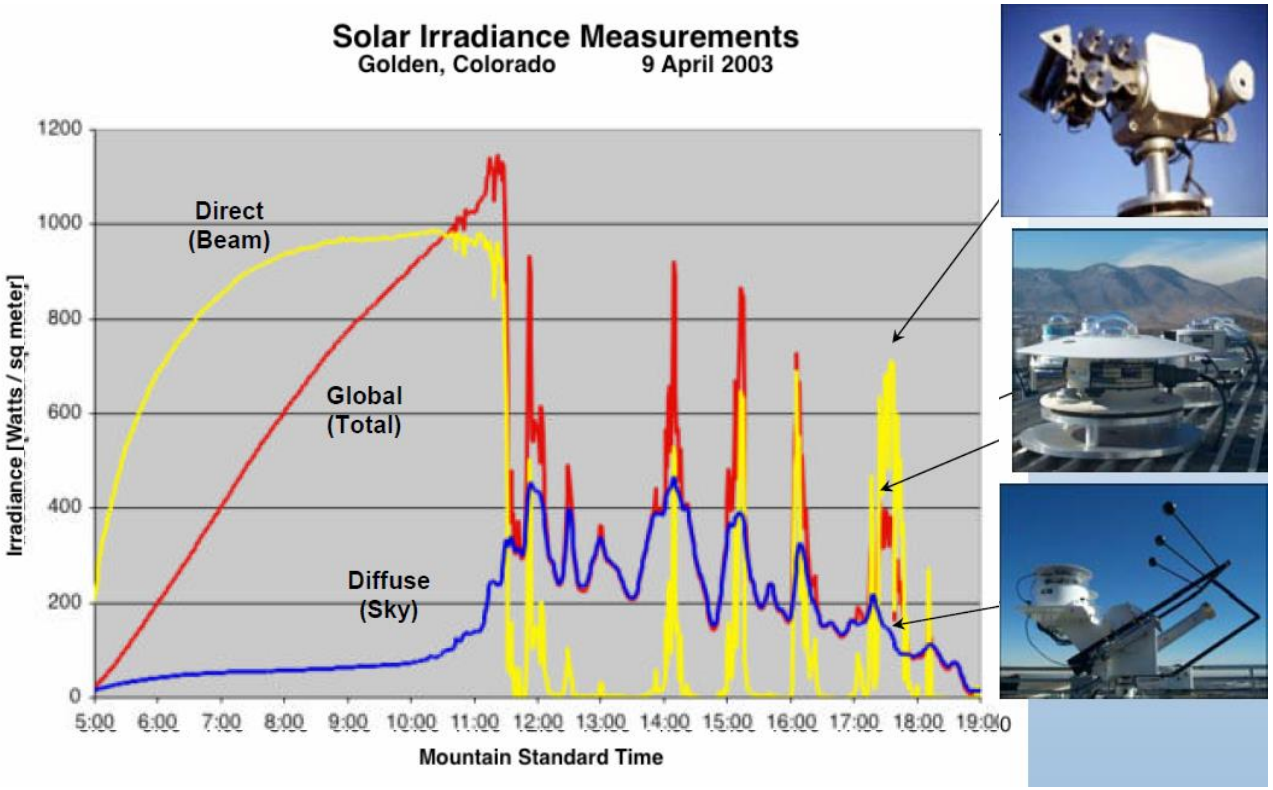
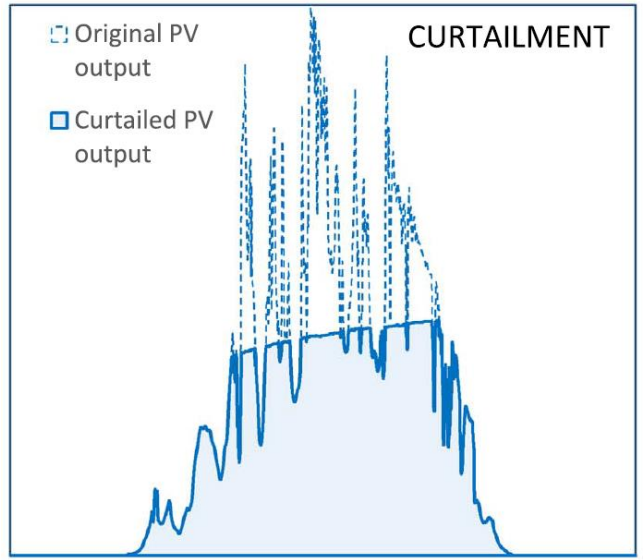
Motivation

- Why we need forecast?
  - Electricity generated from solar energy is related with weather conditions (variability)
  - Higher levels of solar power on the electric grid can be problematic (curtailment)



[T. Stoffel & S. Wilcox, 2004]



[R. Escobar, 2016]

Samples of sky images

TSI

USI

[Kleissl, 2013]

Sky cameras available

Name	Developer	Image format	Commercially available
TSI-800	YES	JPG	???
USI	UCSD	PNG	Yes
SW-02 All sky imager	Steady-Sun	JPG	Yes
ASI-16 All Sky Imager	Eko Instruments	HDR JPG	Yes

[Chow et al., 2011]

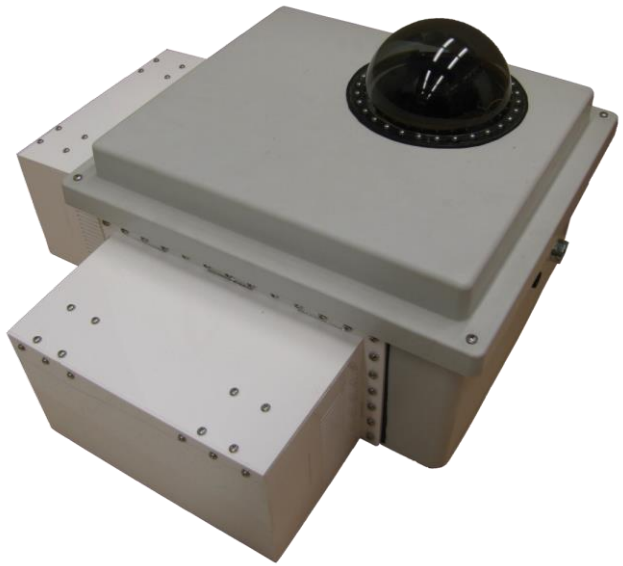
[steadysun]

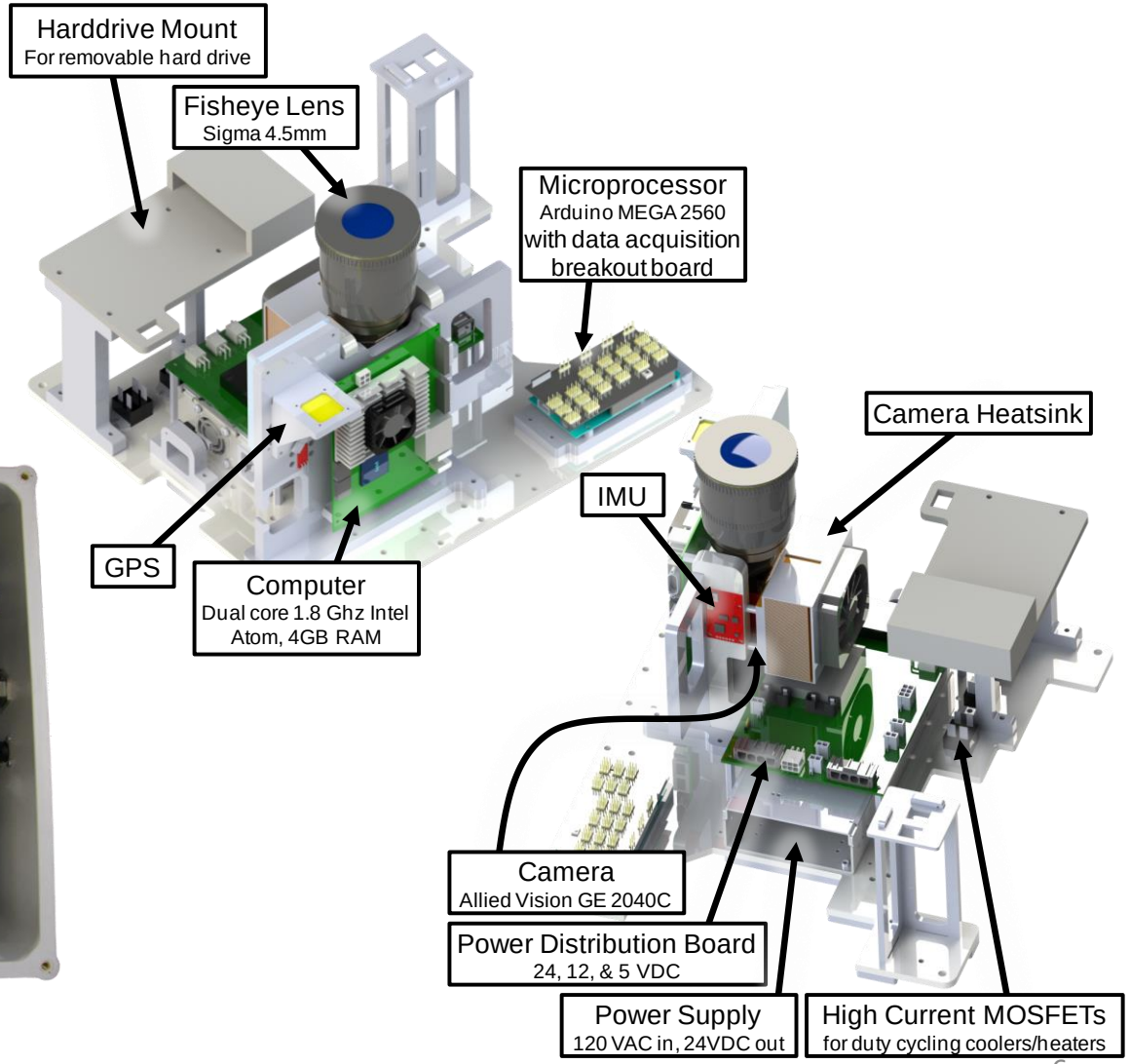
[Chow et al., 2015]

[EKO]

UCSD Sky Imager (USI)

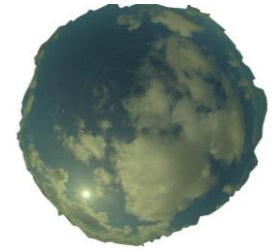
- Developed specifically for solar forecasting
- High Dynamic Range images
- Shadowband is not necessary





[Chow et al., 2015]

Sky Imager Forecast Procedure



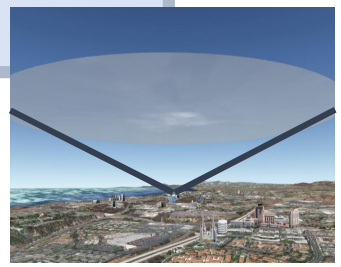
Calibrated Imagery

Detect Cloud

Compute Motion

Forecast future position

Cloud Base Height Data

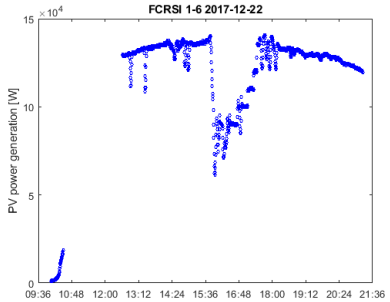


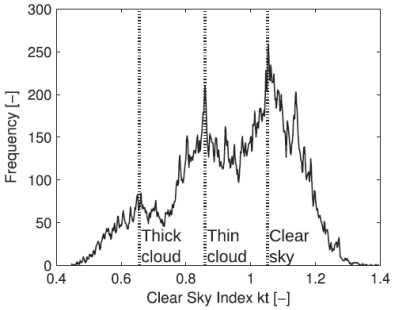
Ray trace shadows

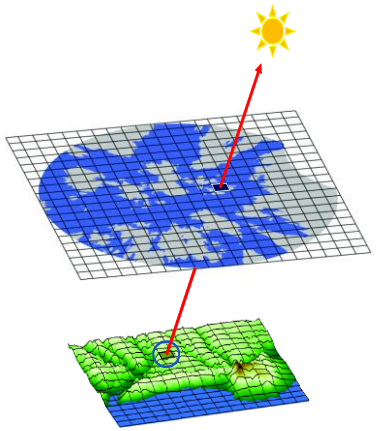
Power Forecast

Data of power or irradiance

Determine cloud attenuation

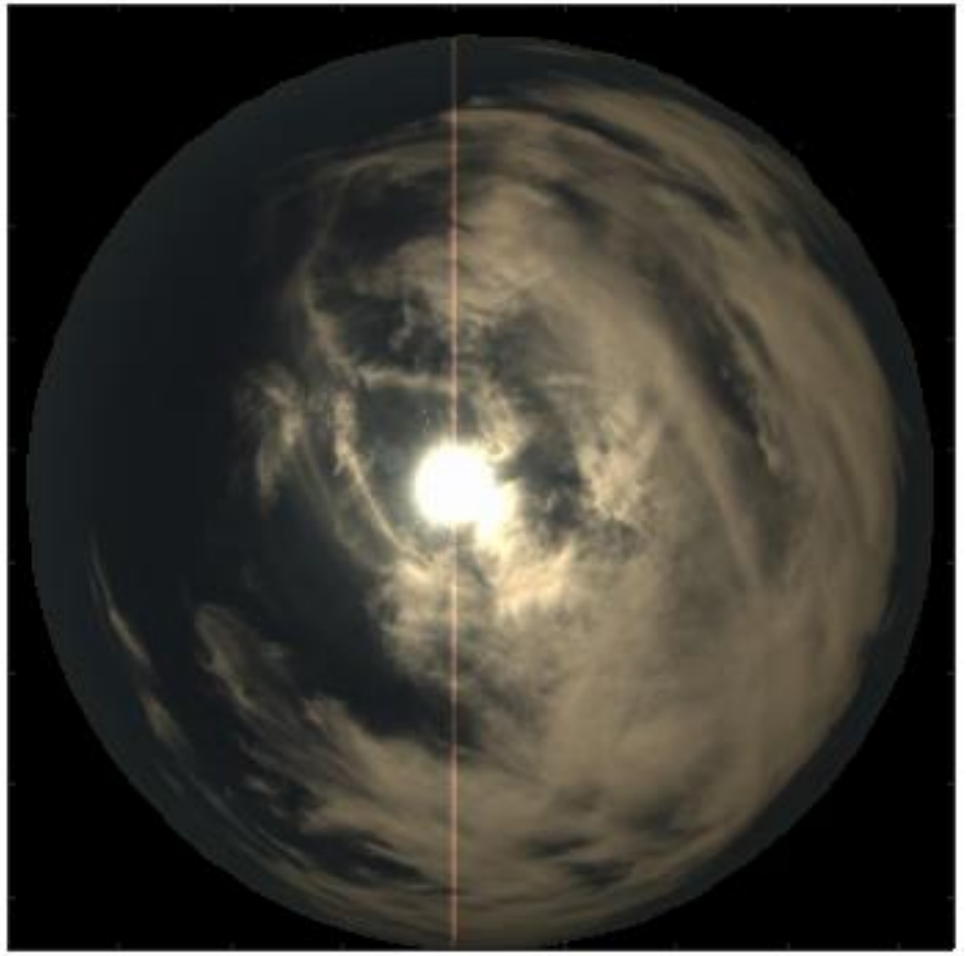




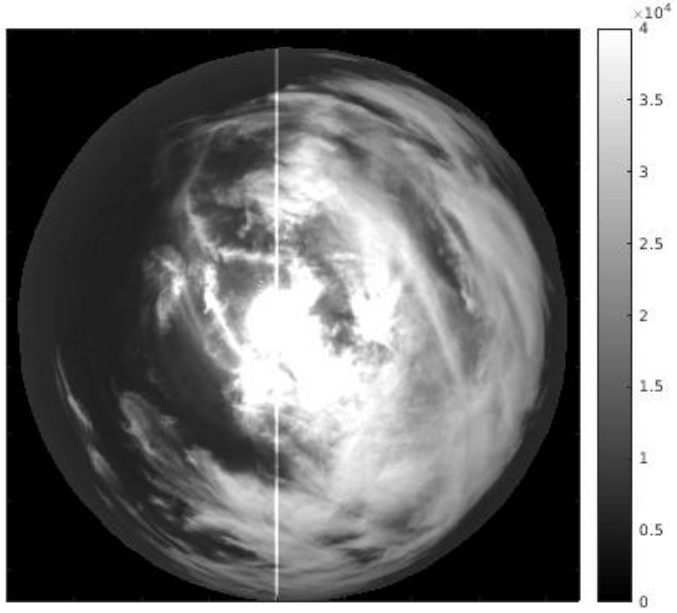


[Chow et al., 2015]

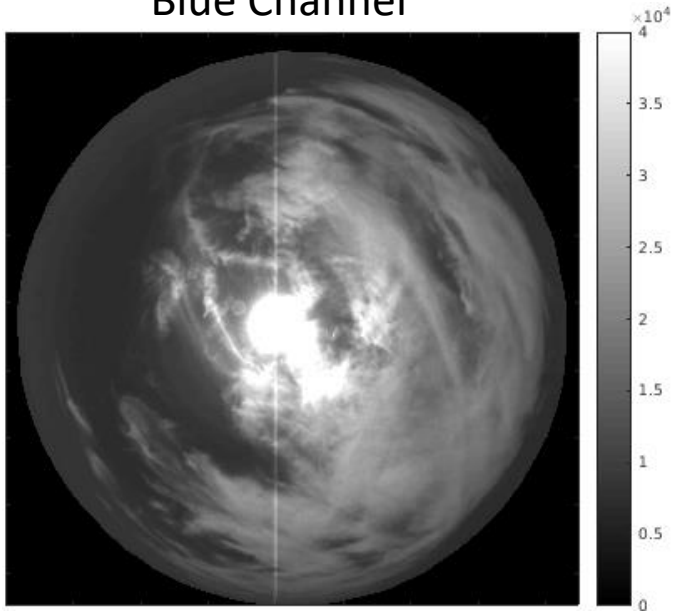
Data processing



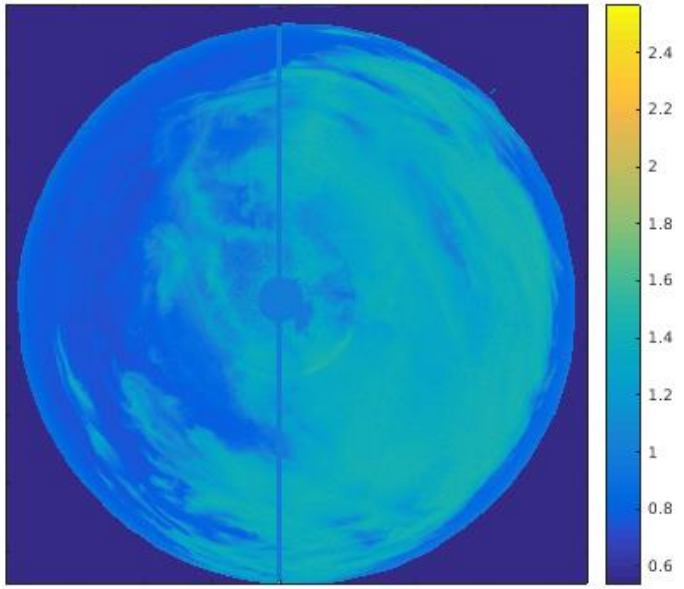
Red Channel



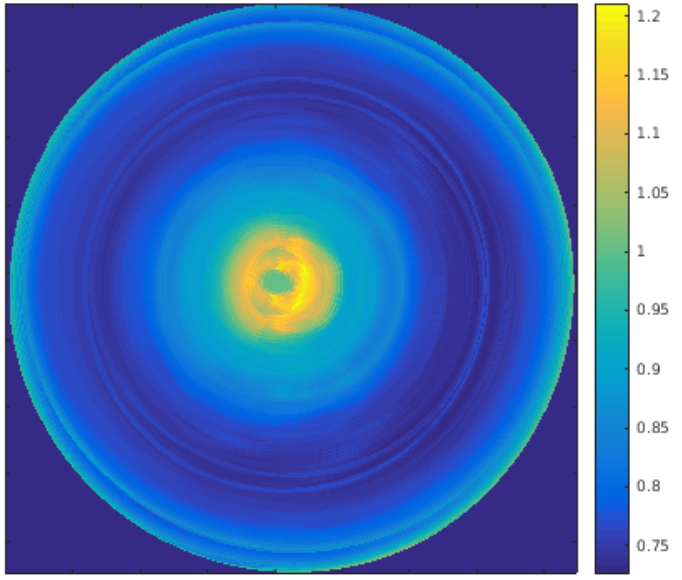
Blue Channel



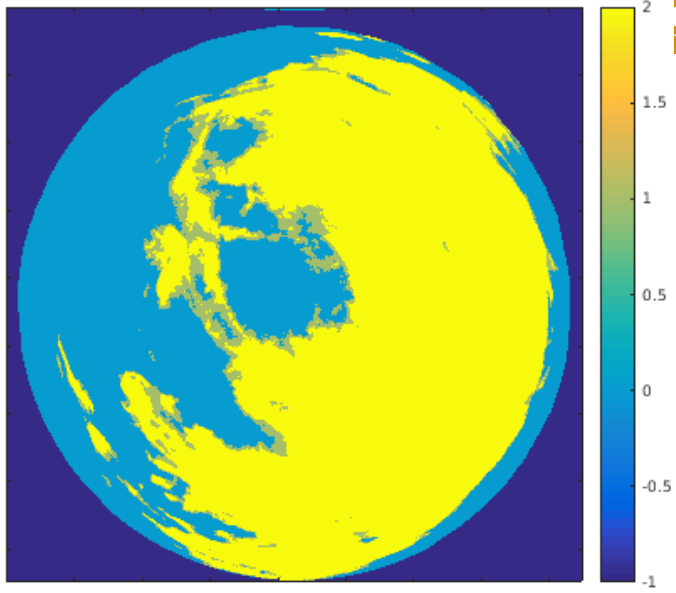
Red - Blue ratio



Clear Sky Library



Cloud Decision



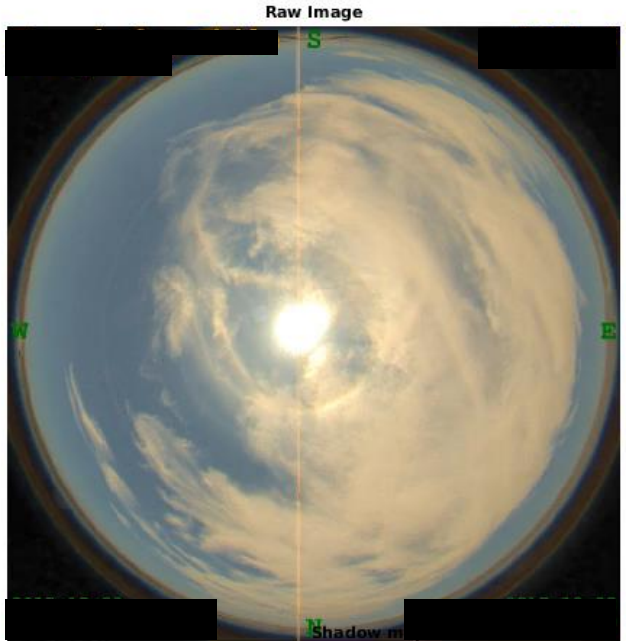
0: clear sky
1: thin cloud
2: thick cloud

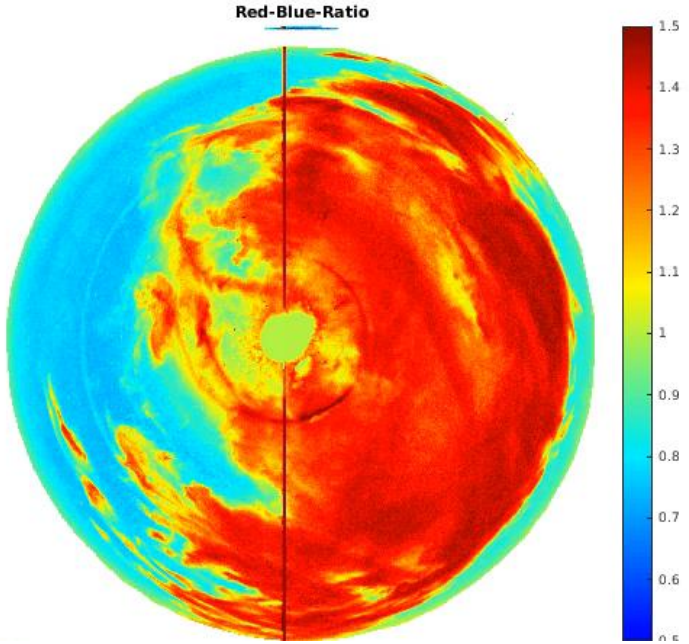
Clear sky images for a whole day were processed

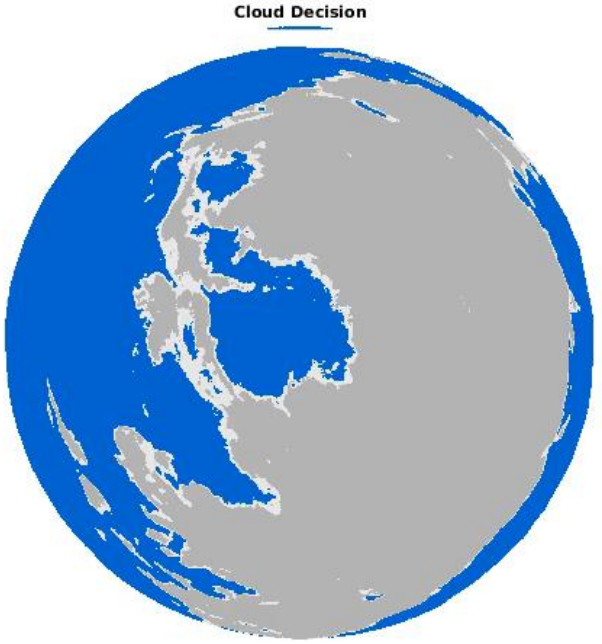
A Clear Sky Library is built

2017-12-22 17:01:30 UTC

Preliminary Results

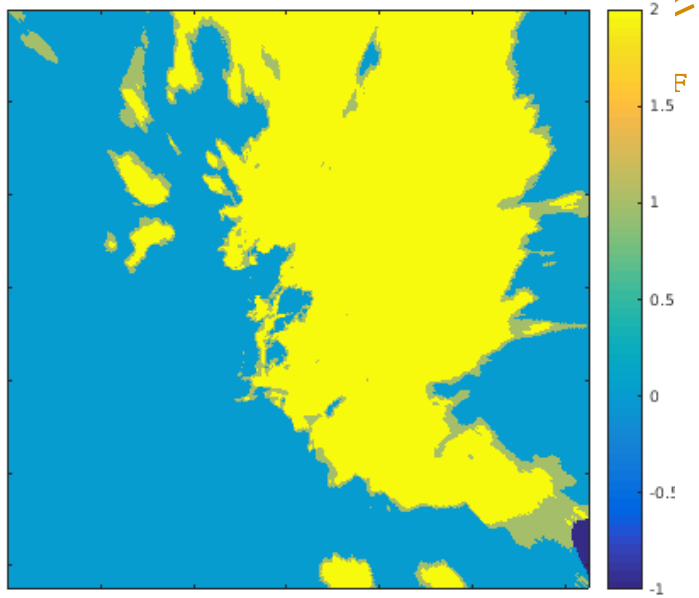




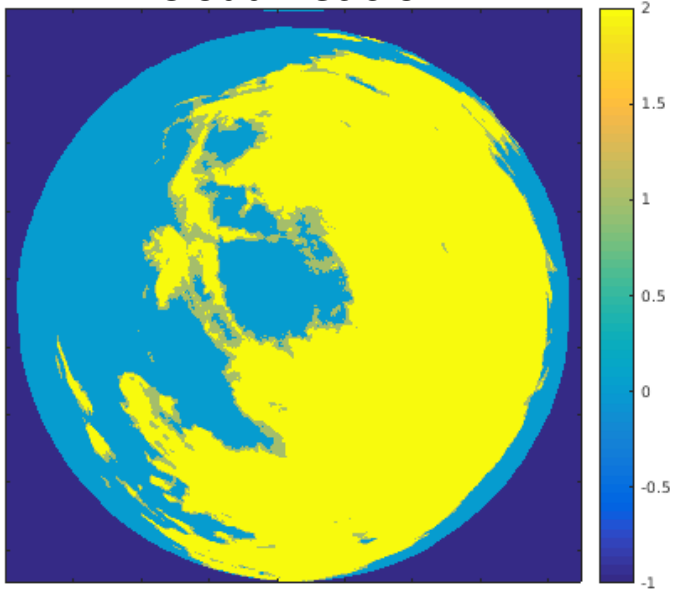


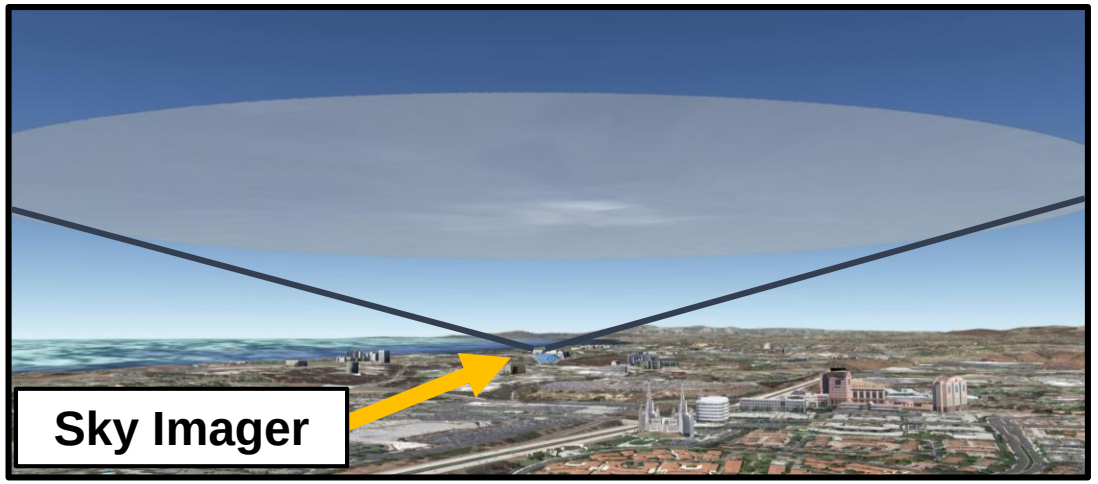
Deployment

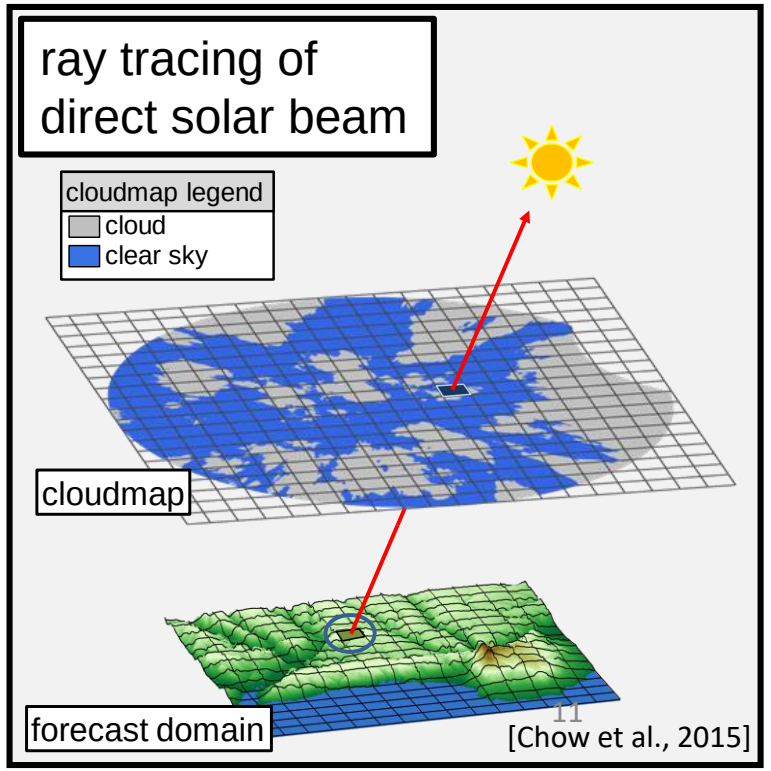
Projection



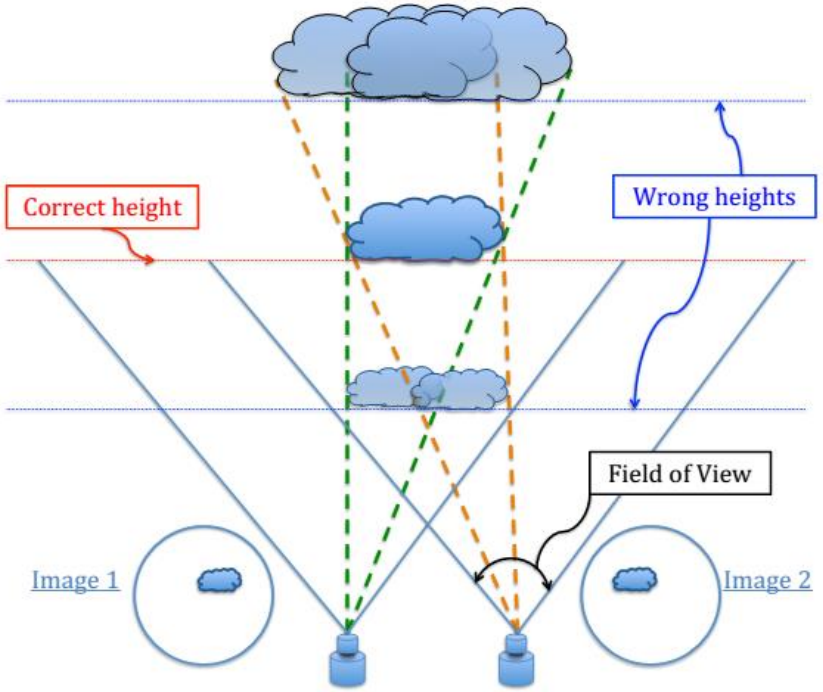
Cloud Decision





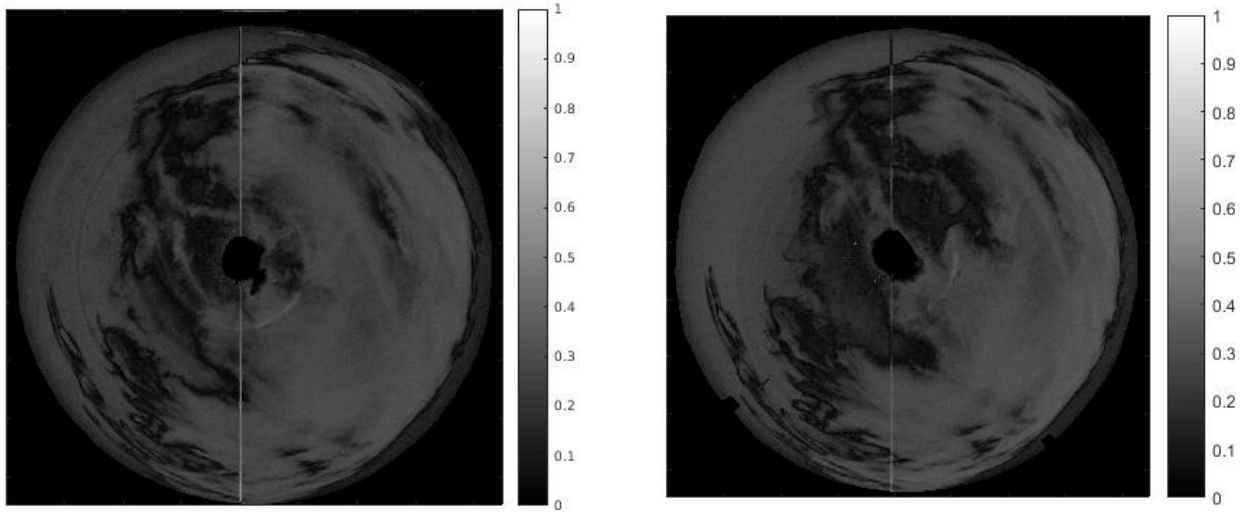


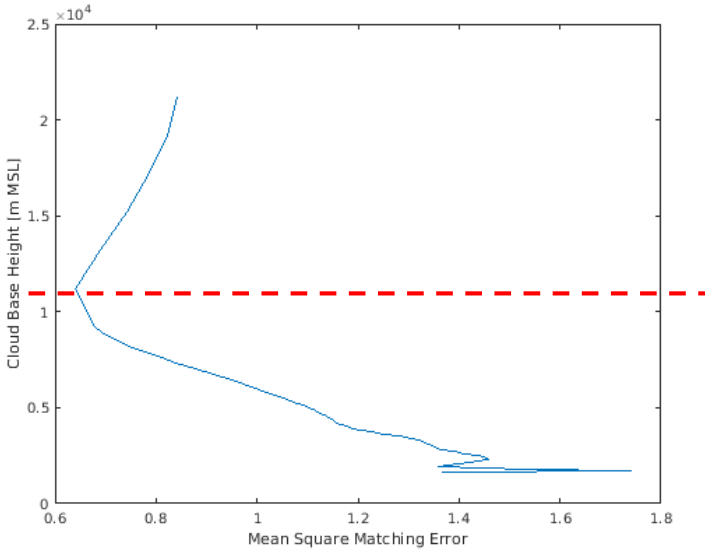
Estimating Cloud Base Height (CBH)



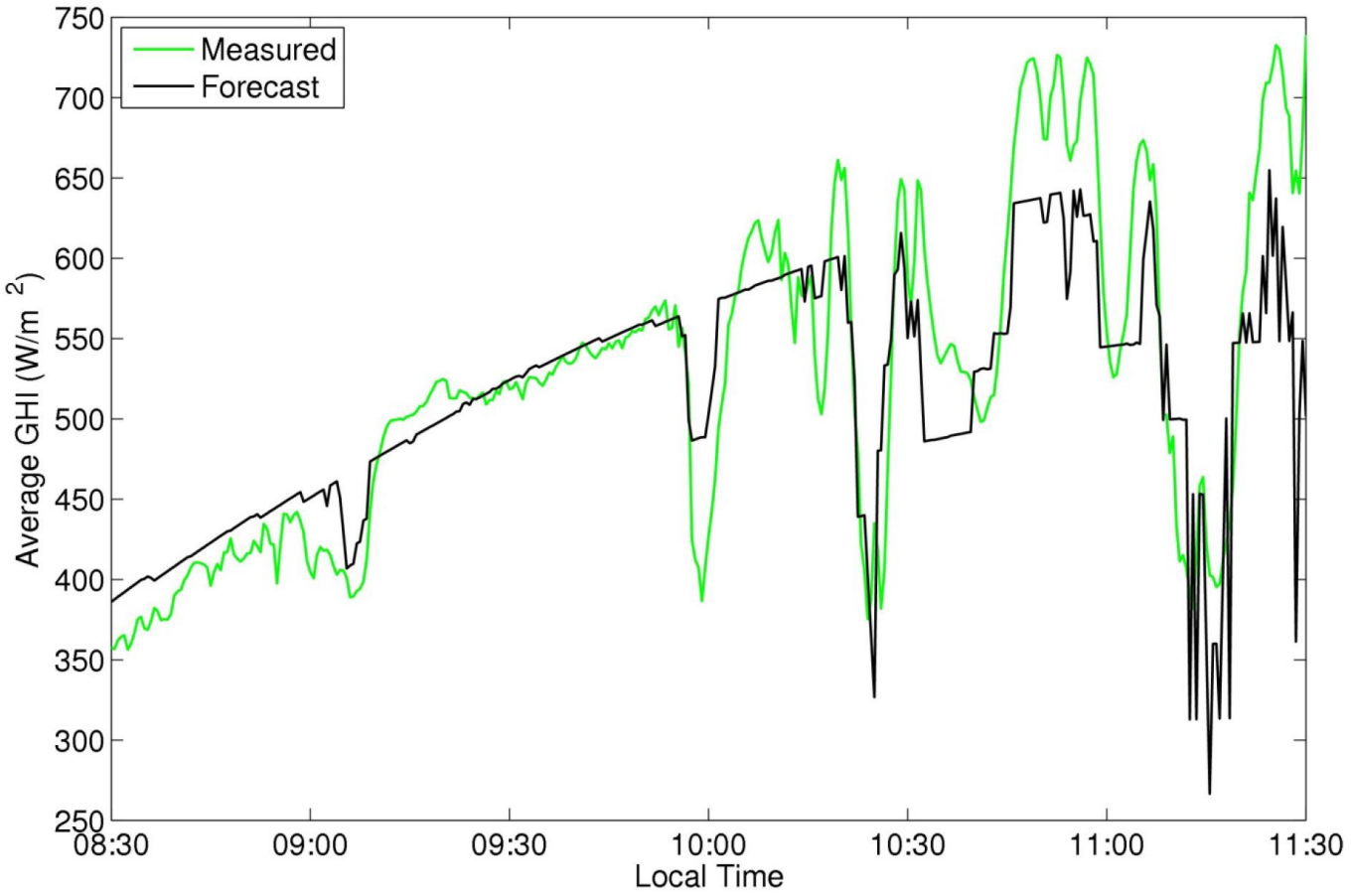
[Nguyen and Kleissl, 2014]

$$\epsilon_h = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(s_1^i - s_2^i)^2}$$





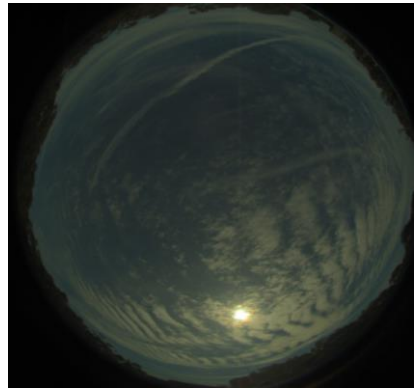
Final Results

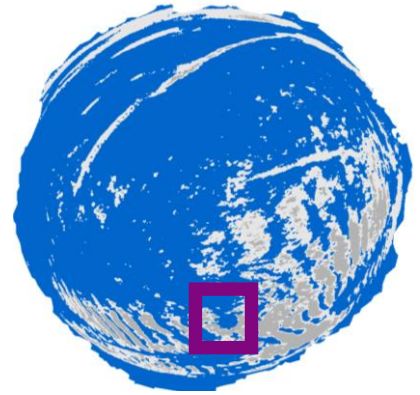


[Kleissl, 2013]

Limitations

- Solar region issues
- Estimating cloud base height is not easy
- Clouds behavior
  - Shape is not constant
  - More than one layer of clouds





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