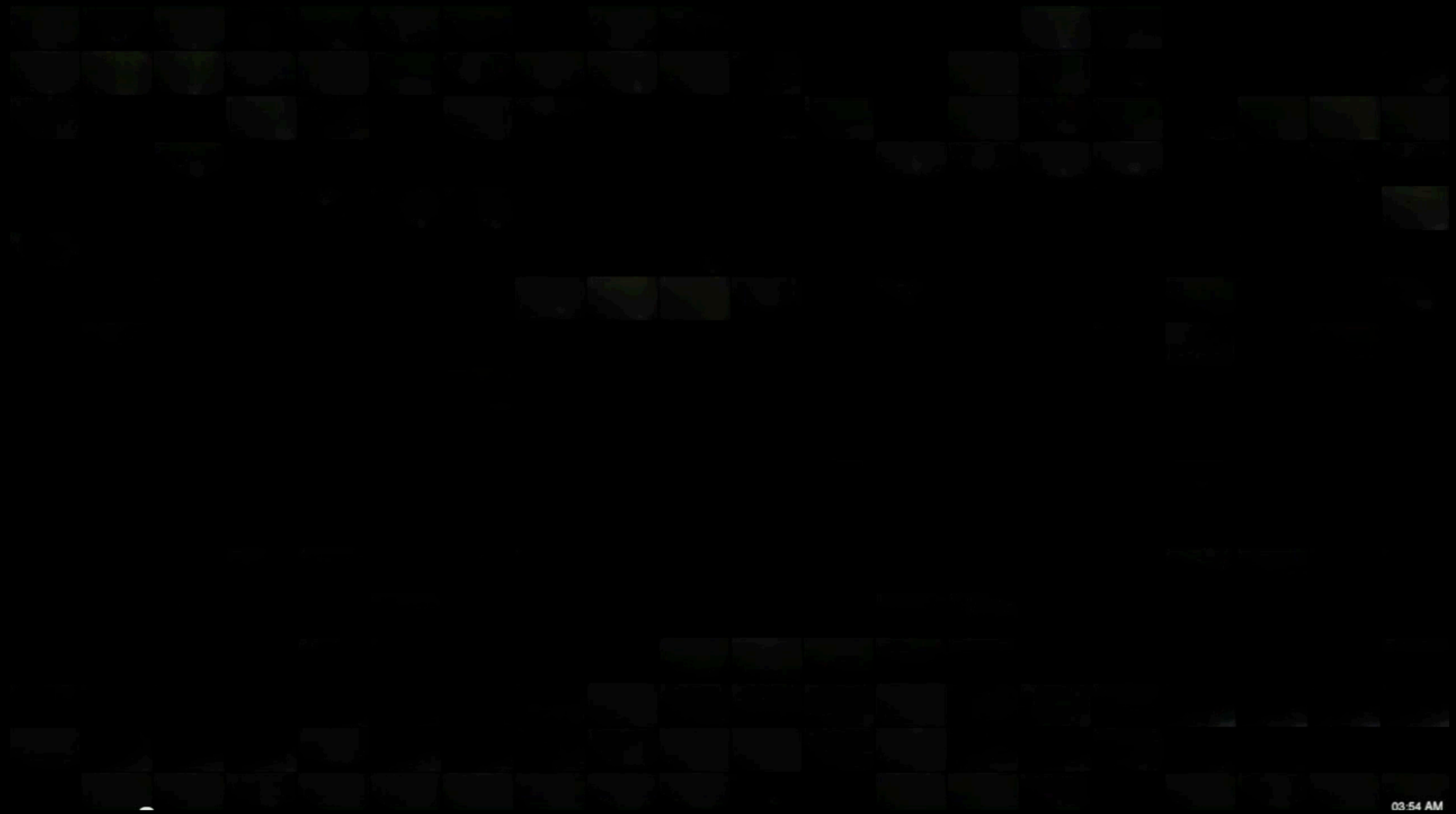
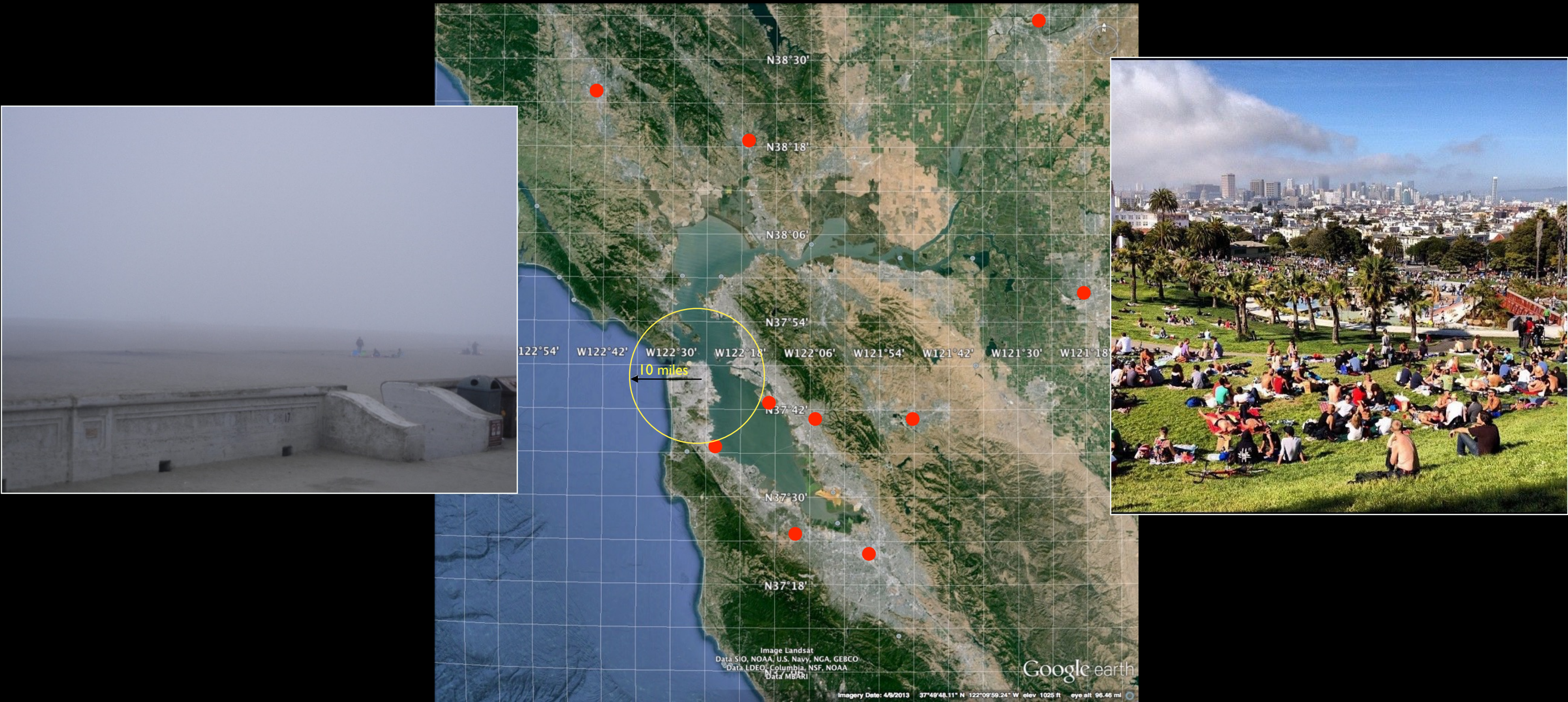


Leveraging real-time, HDR sky-maps



03:54 AM





Bay area weather station locations within the TMY network



Pyranometer 1:  
diffuse horizontal  
irradiance

Pyranometer 2:  
global horizontal  
irradiance

Shading disc for  
pyranometer 1

Pyrheliometer:  
direct normal  
irradiance

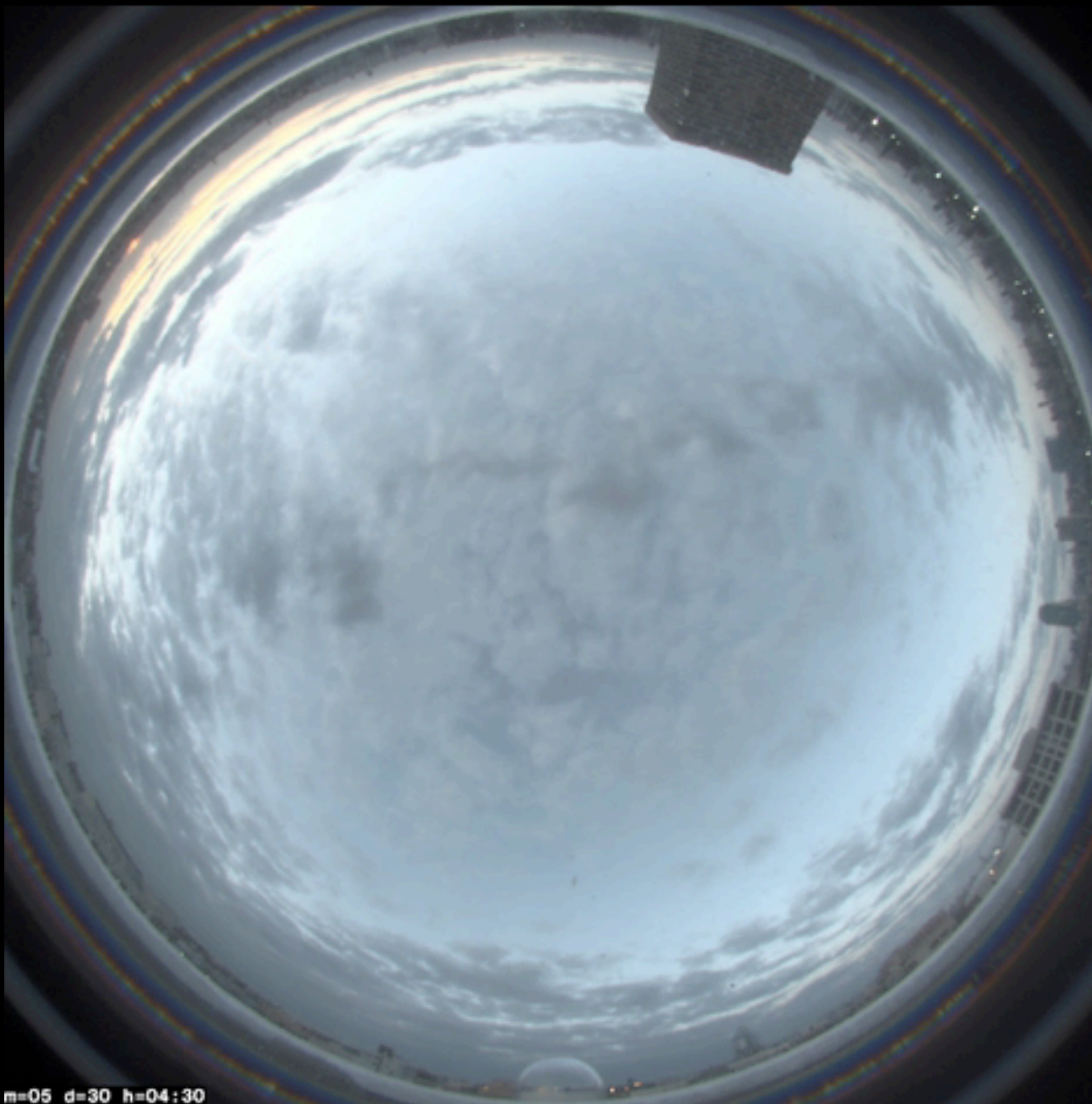
Solar tracker:  
follows altitude  
and azimuth of  
sun



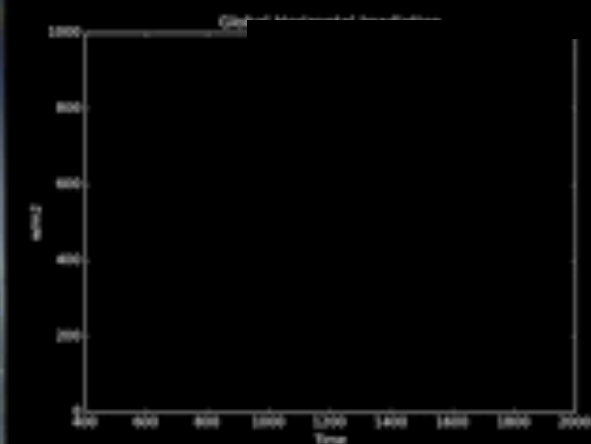


# Skyometer

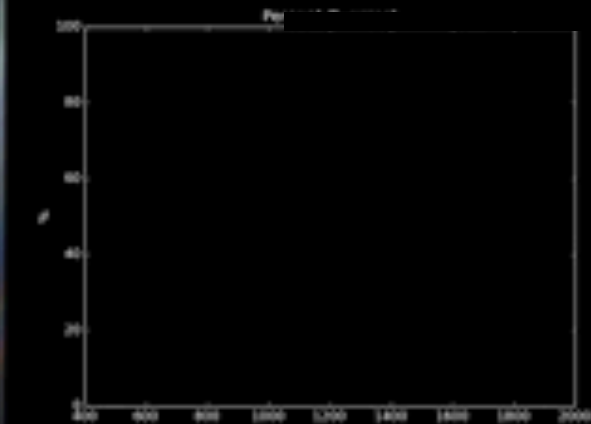




Cloud Direction



Global Horizontal Irradiation



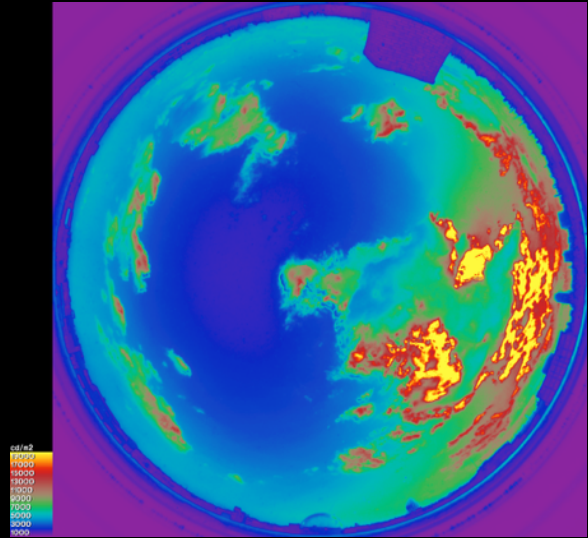
% Overcast



Metrics



- Global Horizontal Illuminance (fc)
- Direct Normal Illuminance (fc)
- Diffuse Horizontal Illuminance (fc)
- Global Horizontal Radiation (w/m2)



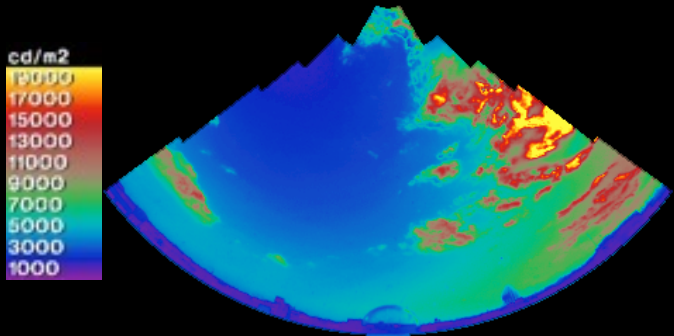
- Sky Brightness (cd/m2)
- Zenith Brightness (k-Nits)



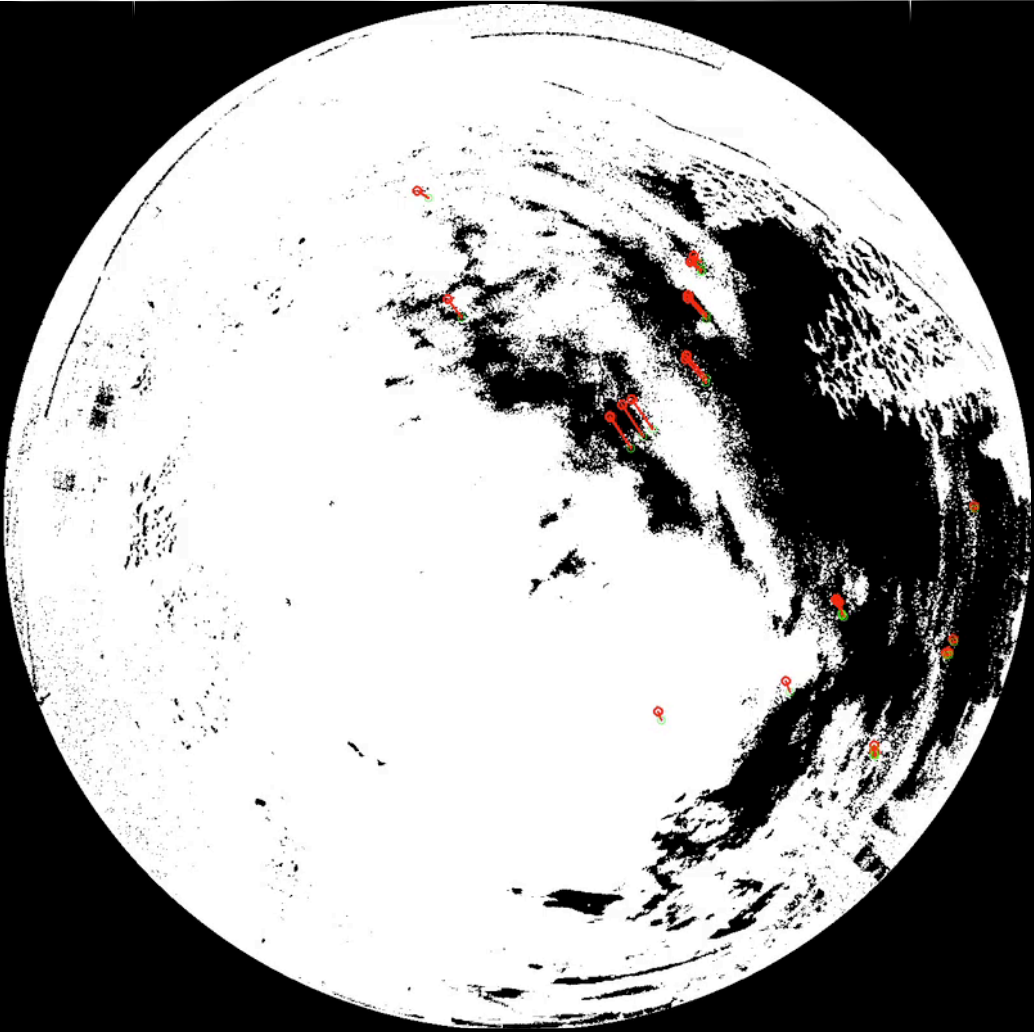
% Overcast



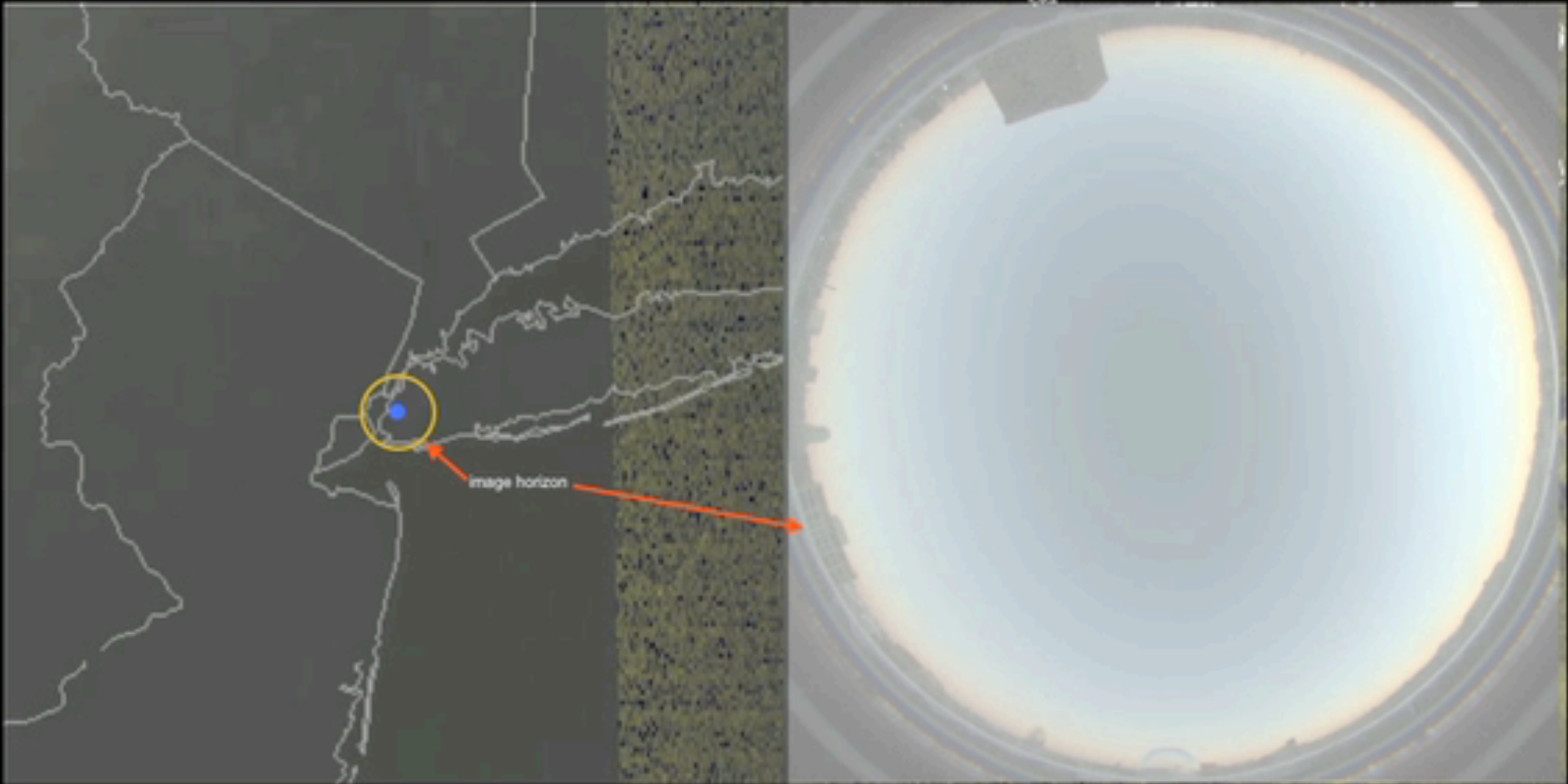
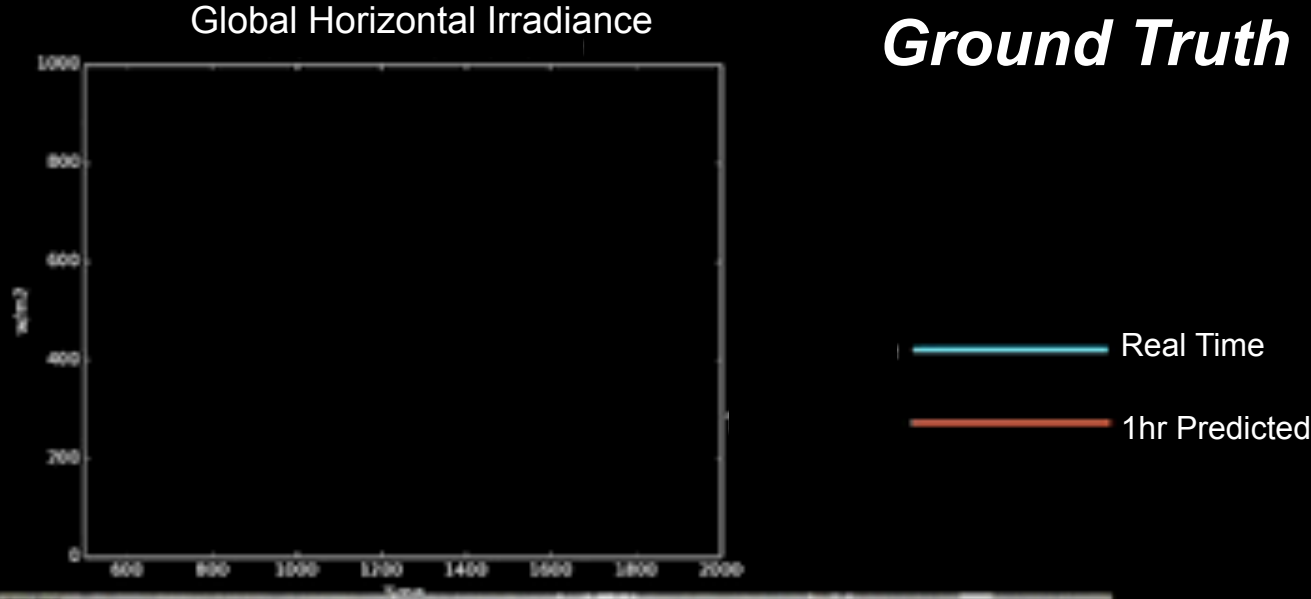
Cloud-Edge Ratio



- Vertical Sky Brightness (cd/m2)
- Vertical Illuminance (fc)
- Vertical Irradiation / Insolation (w/m2)
- Profile Angles (degrees)



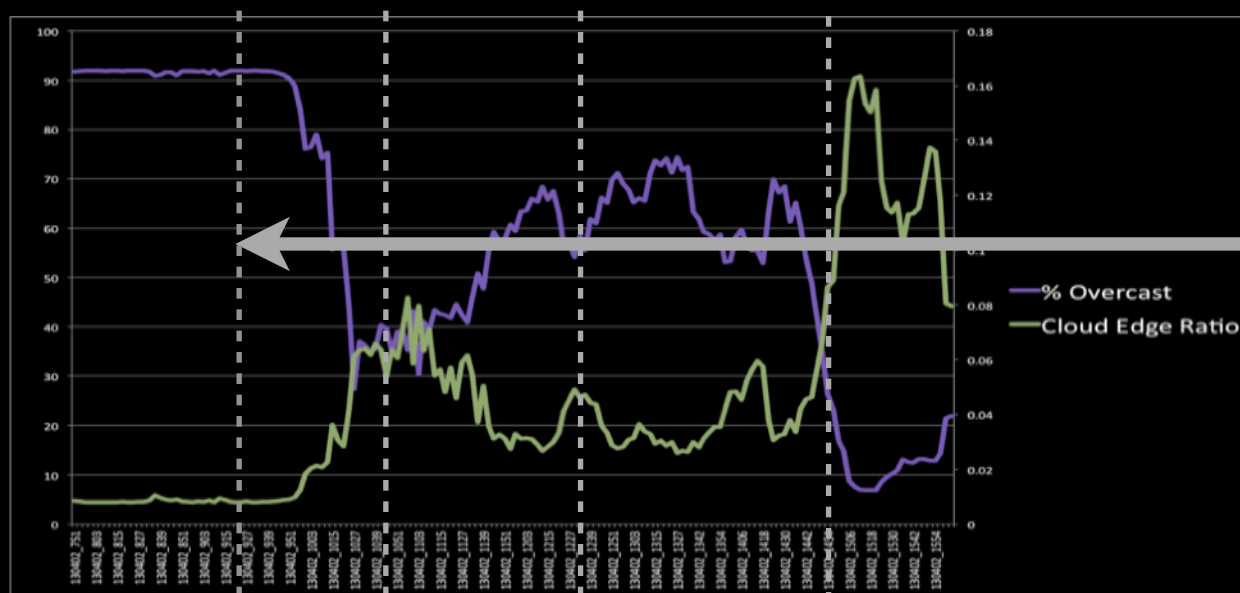
- Cloud Direction (degrees)
- Cloud Speed



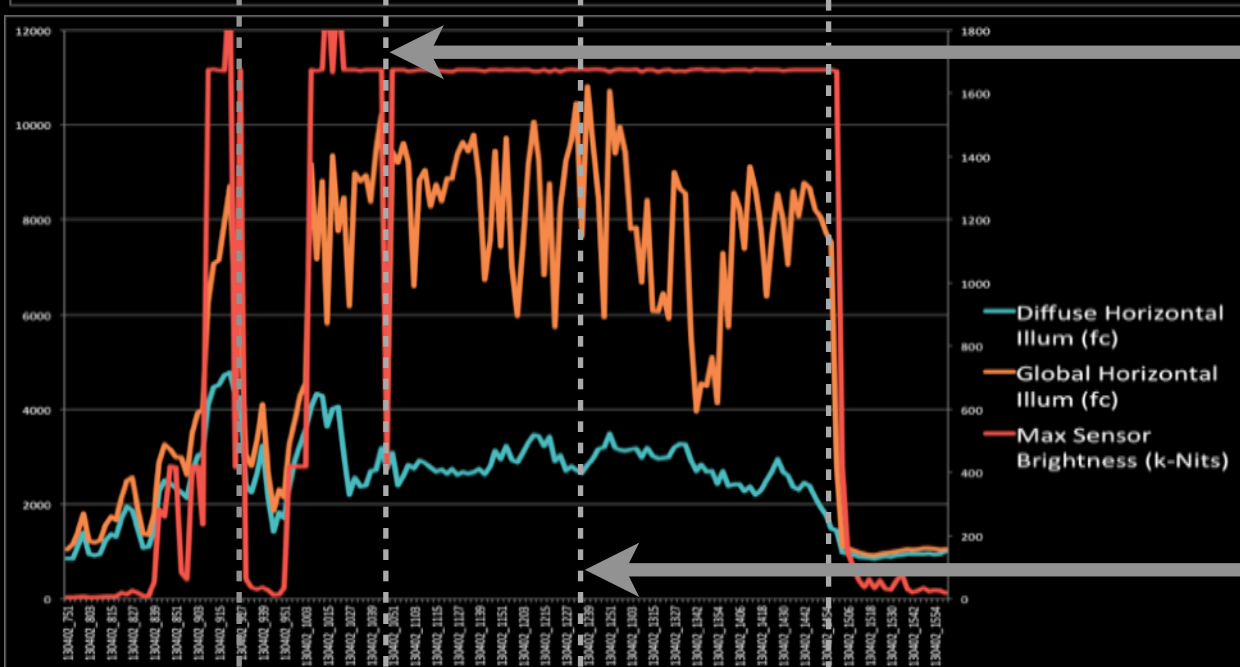
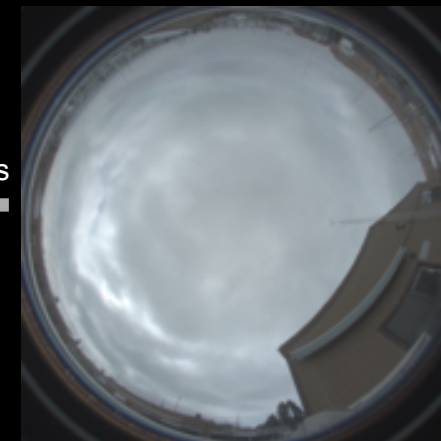
- Satellite - Extraterrestrial View

- Local Site - Terrestrial View





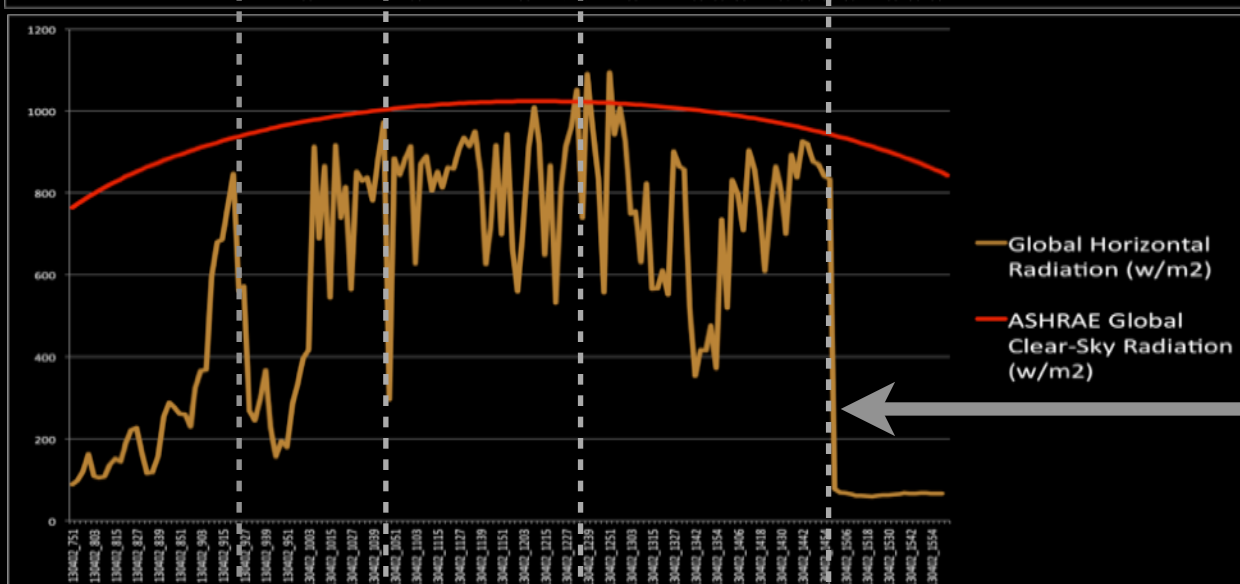
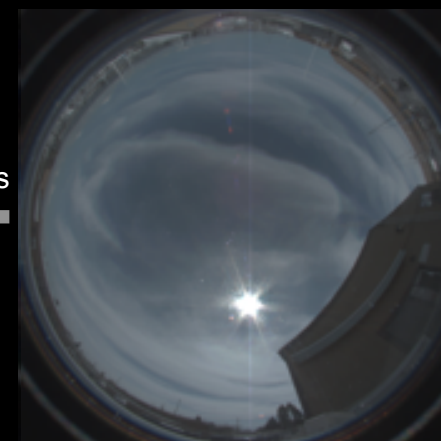
0923 Hrs



1048 Hrs



1230 Hrs

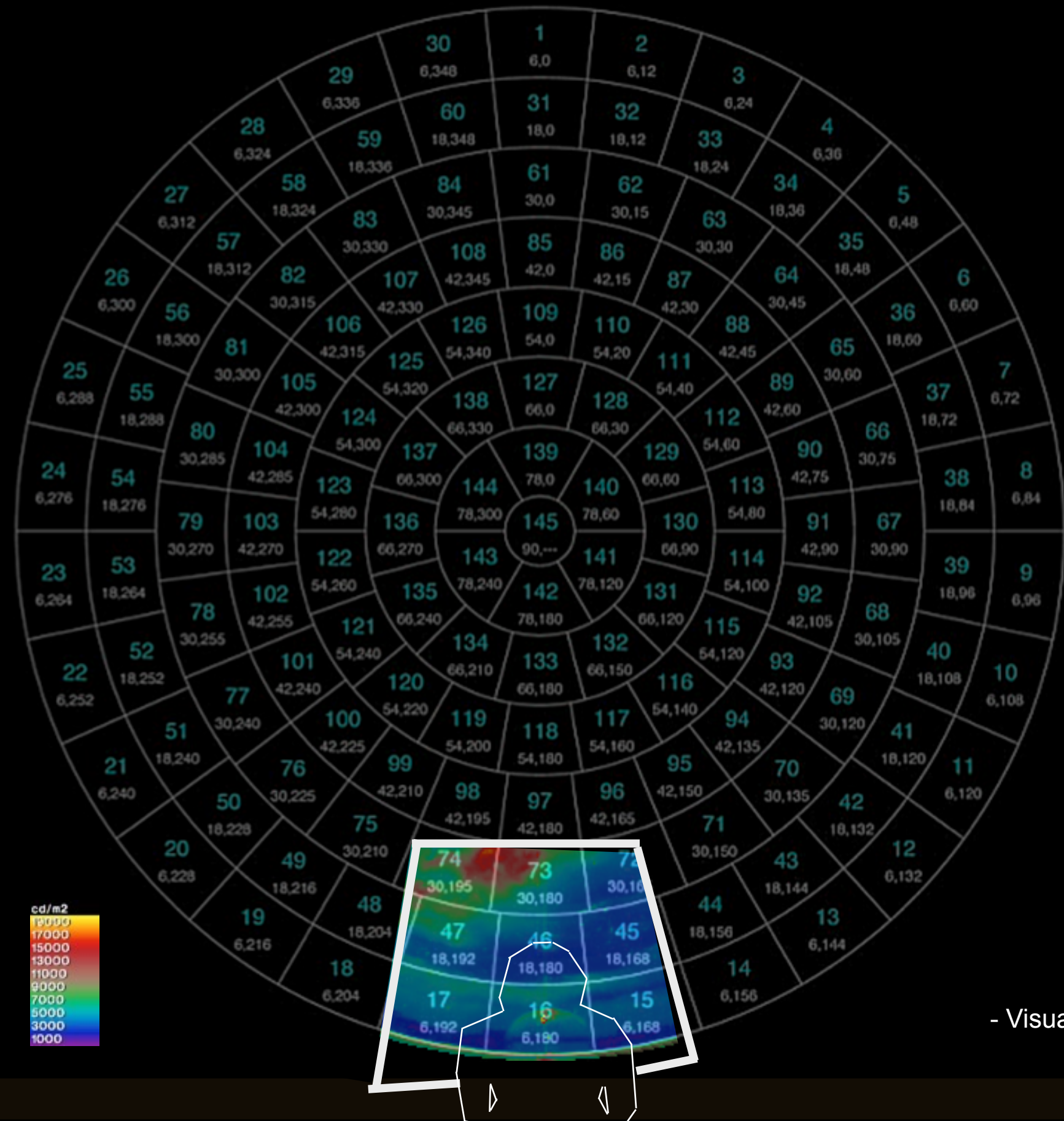


1457 Hrs



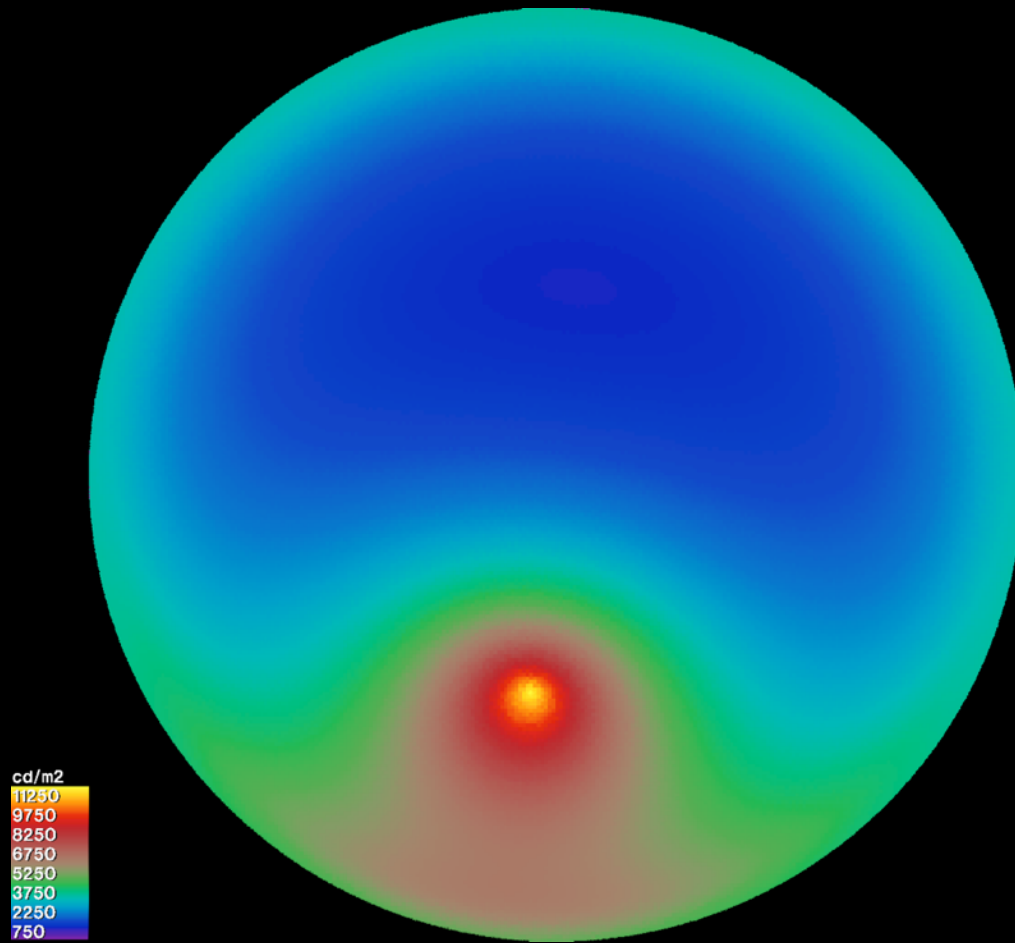
# Sky Patches



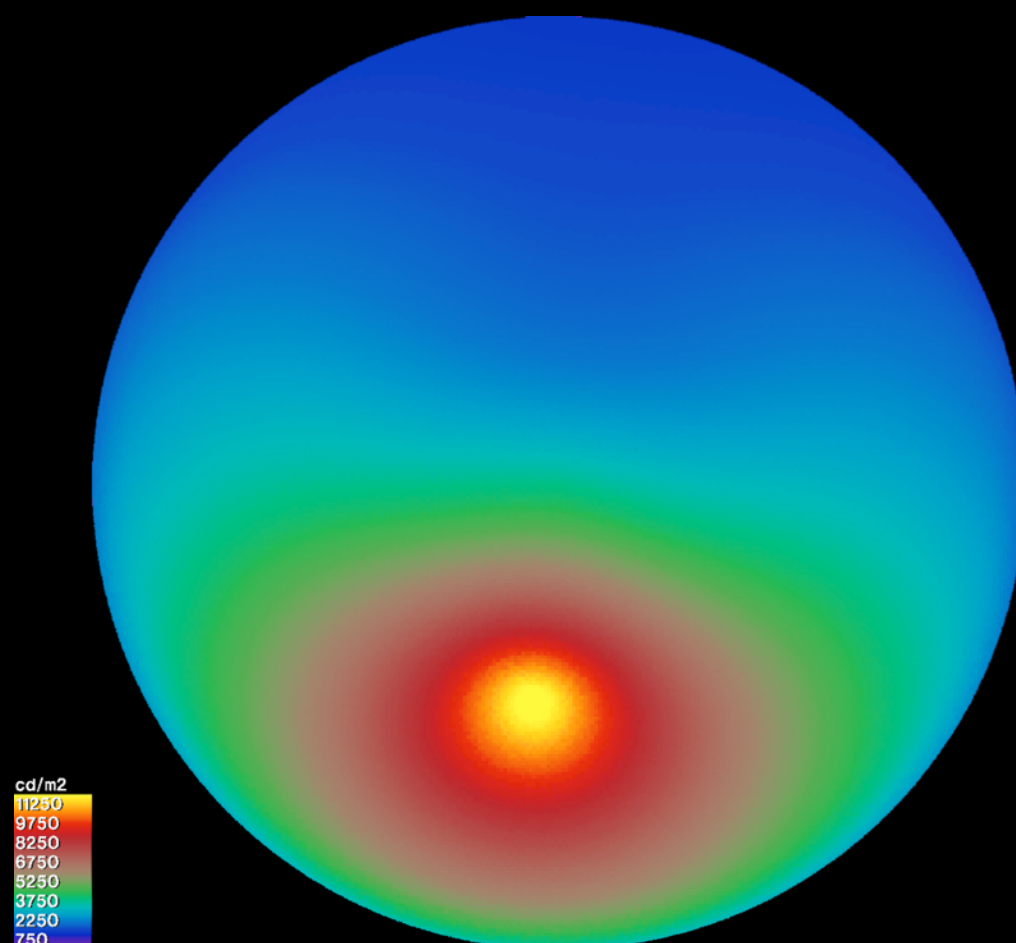


- Visual Glare from sky brightness

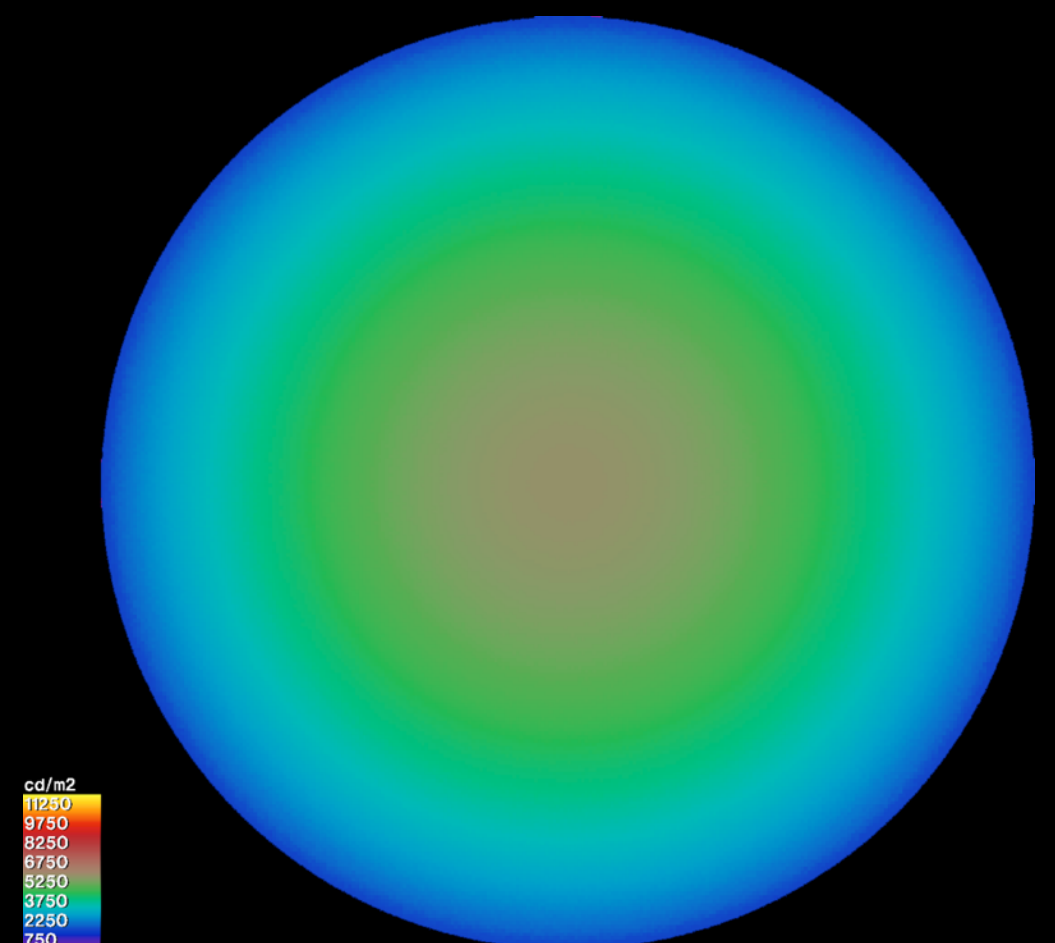
# Physically Based Global Illumination Models



- Clear Sky



- Intermediate Sky



- CIE Overcast Sky





6:03



6:15



6:30



6:45



7:00



7:15



7:30



7:45



8:00



8:15



8:30



8:45



9:00



9:15



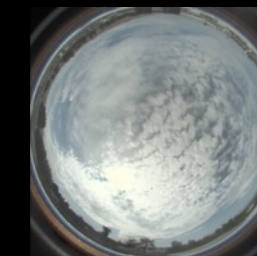
9:30



9:45



10:00



10:15



10:30



10:45



11:00



11:15



11:30



11:45



12:00



12:15



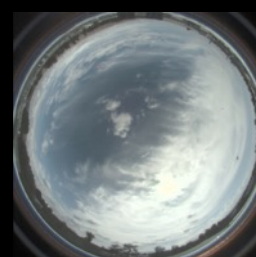
12:30



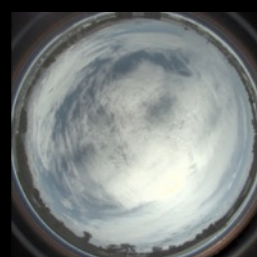
12:45



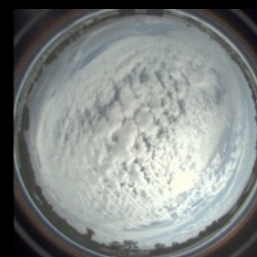
13:00



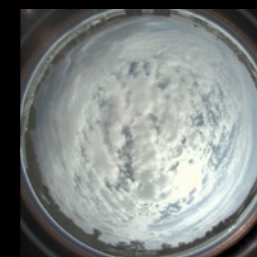
13:15



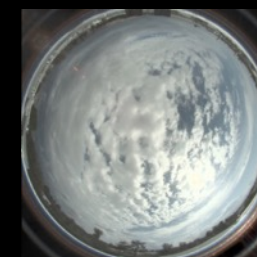
13:30



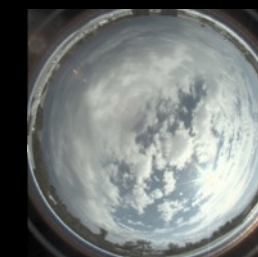
13:45



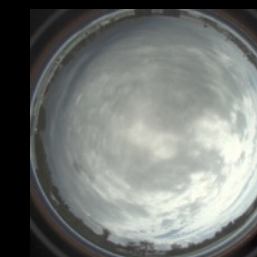
14:00



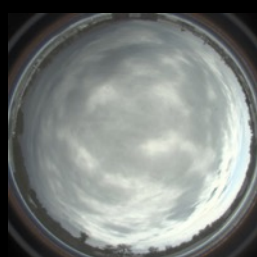
14:15



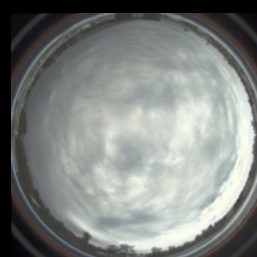
14:30



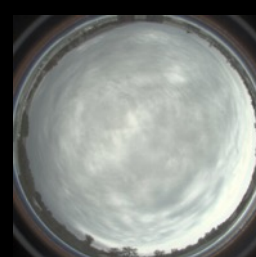
14:45



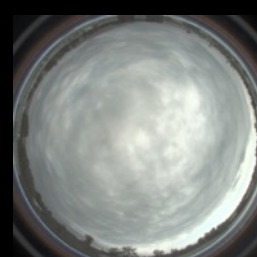
15:00



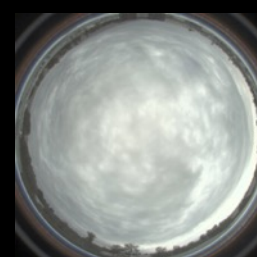
15:15



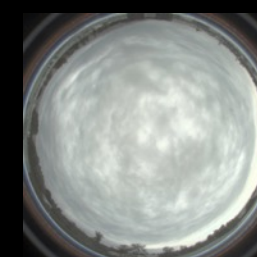
15:30



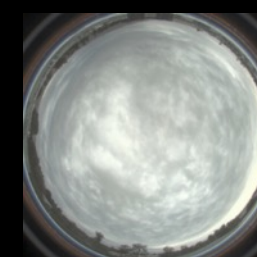
15:45



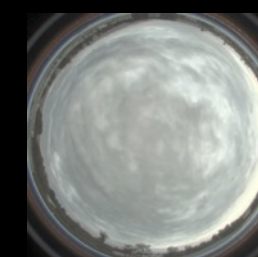
16:00



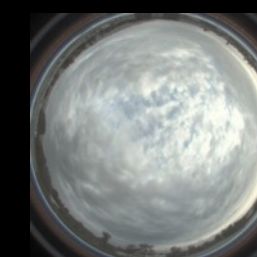
16:15



16:30



16:45



17:00



17:15



17:30



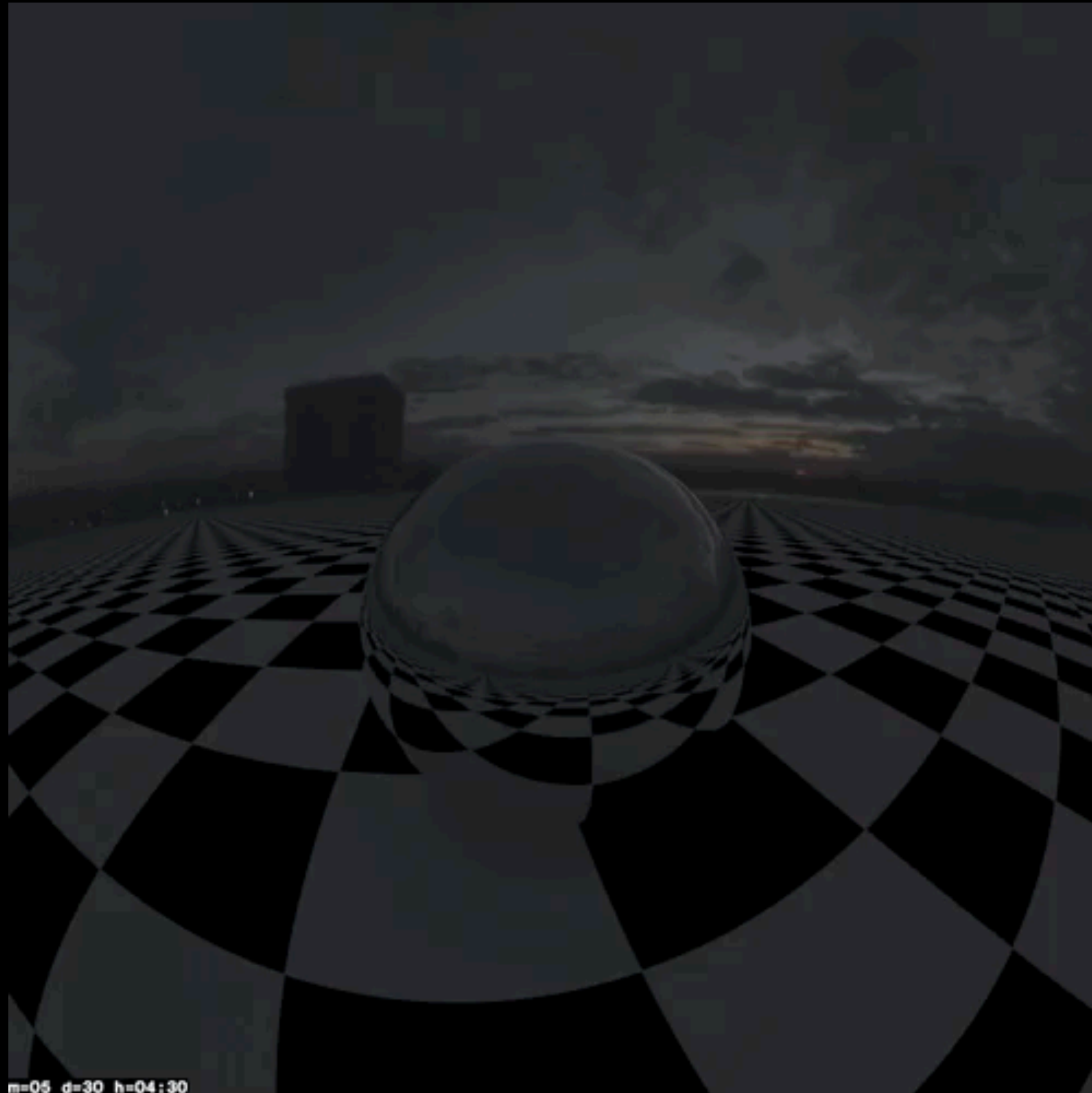
17:45



18:00



# Image Based Global Illumination Models







Camera Horizontal



Camera Vertical





Physical Model



3D Model



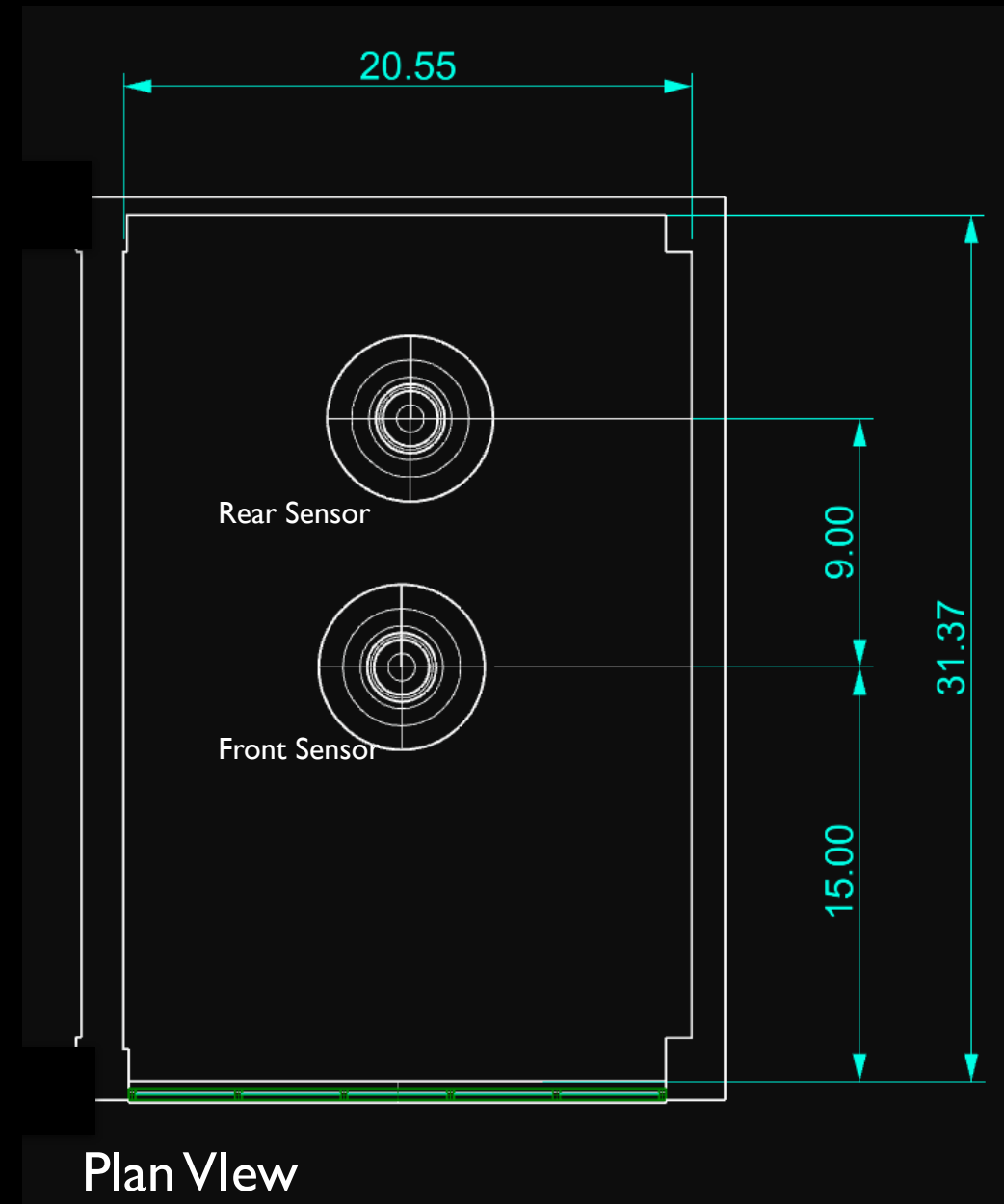
-rtrace parameter settings: '-l+ -aa 0 -ab 16 -ad 64000 -lr -24 -lw 1e-10 -dc 1 -ds 0 -u+'

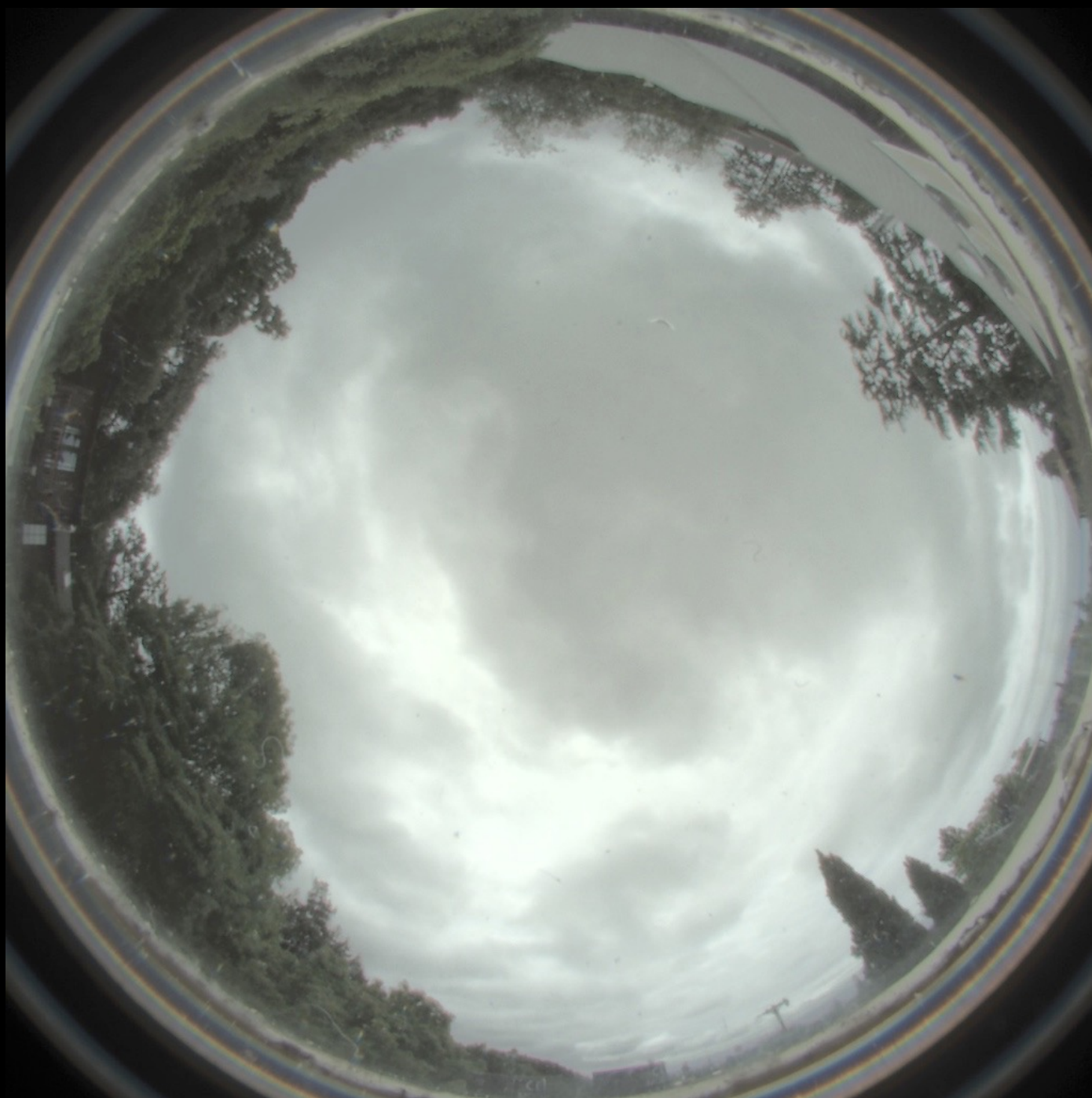
-Ground hemisphere: 35% reflectance

-All modeled surface reflectances measured with PGE's Minolta Spectrophotometer CM-2600d

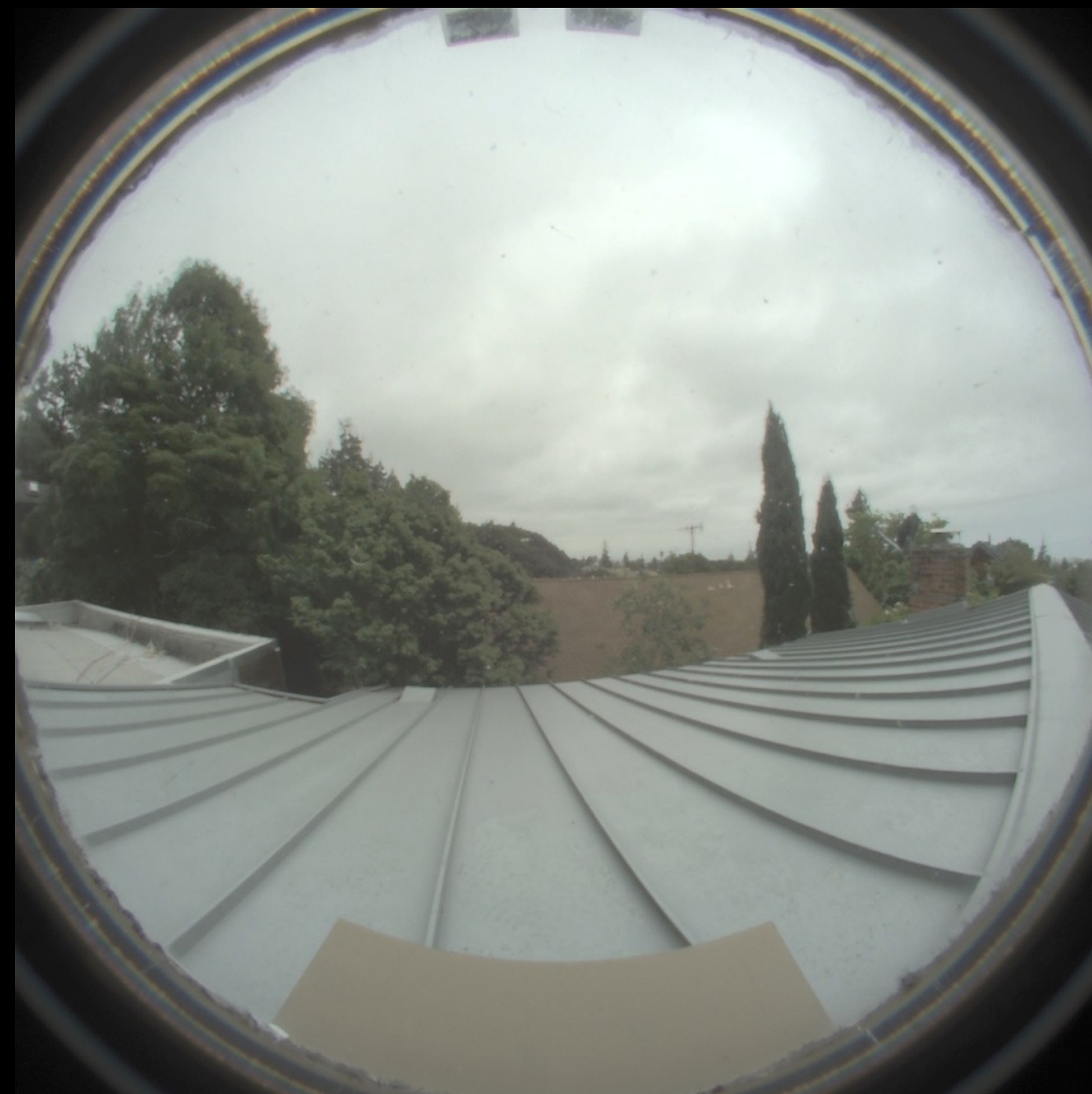
-Front sensor 15'-0" from South window wall

-Rear sensor 24'-0" from South window wall





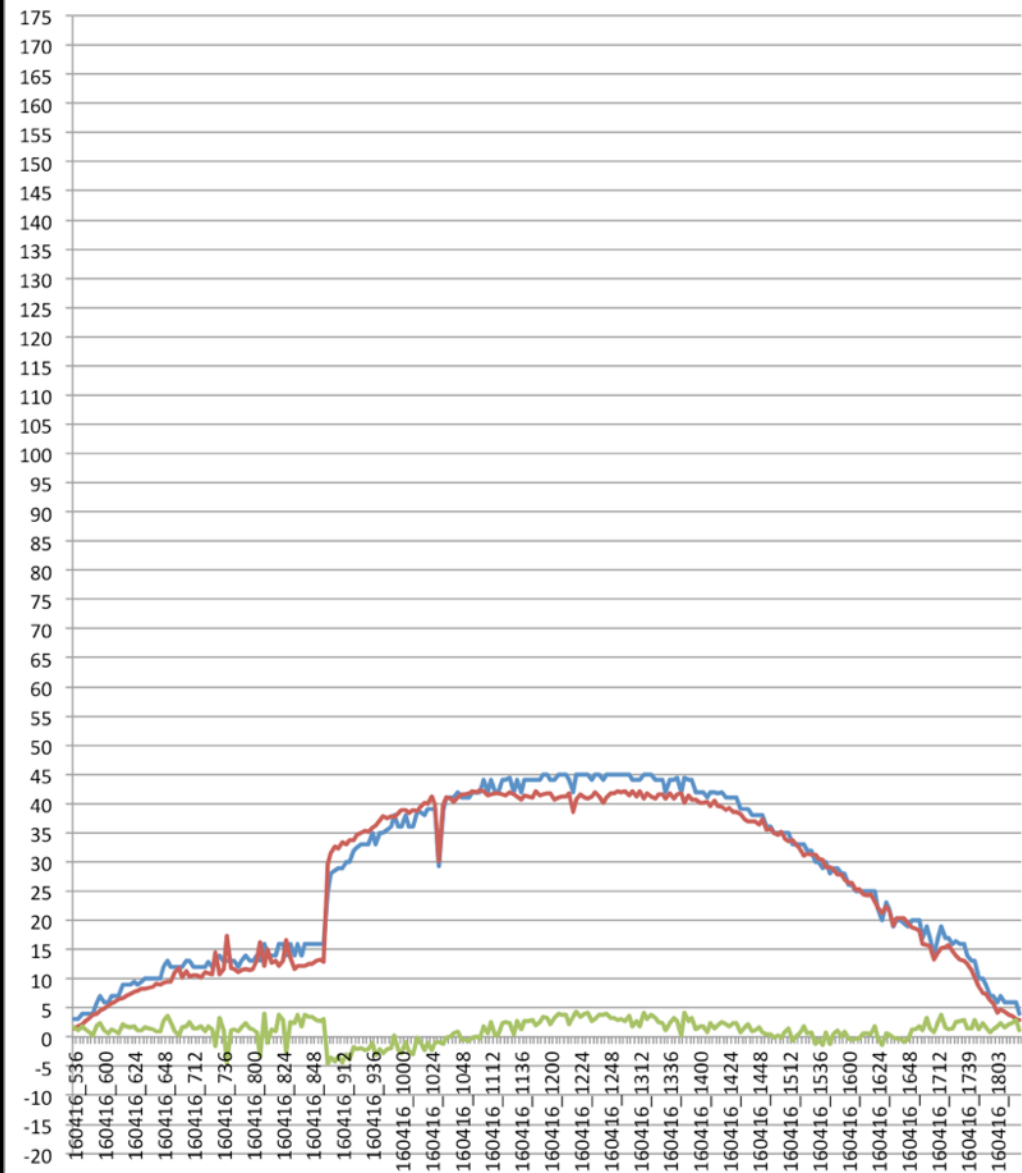
Camera Horizontal - North Up



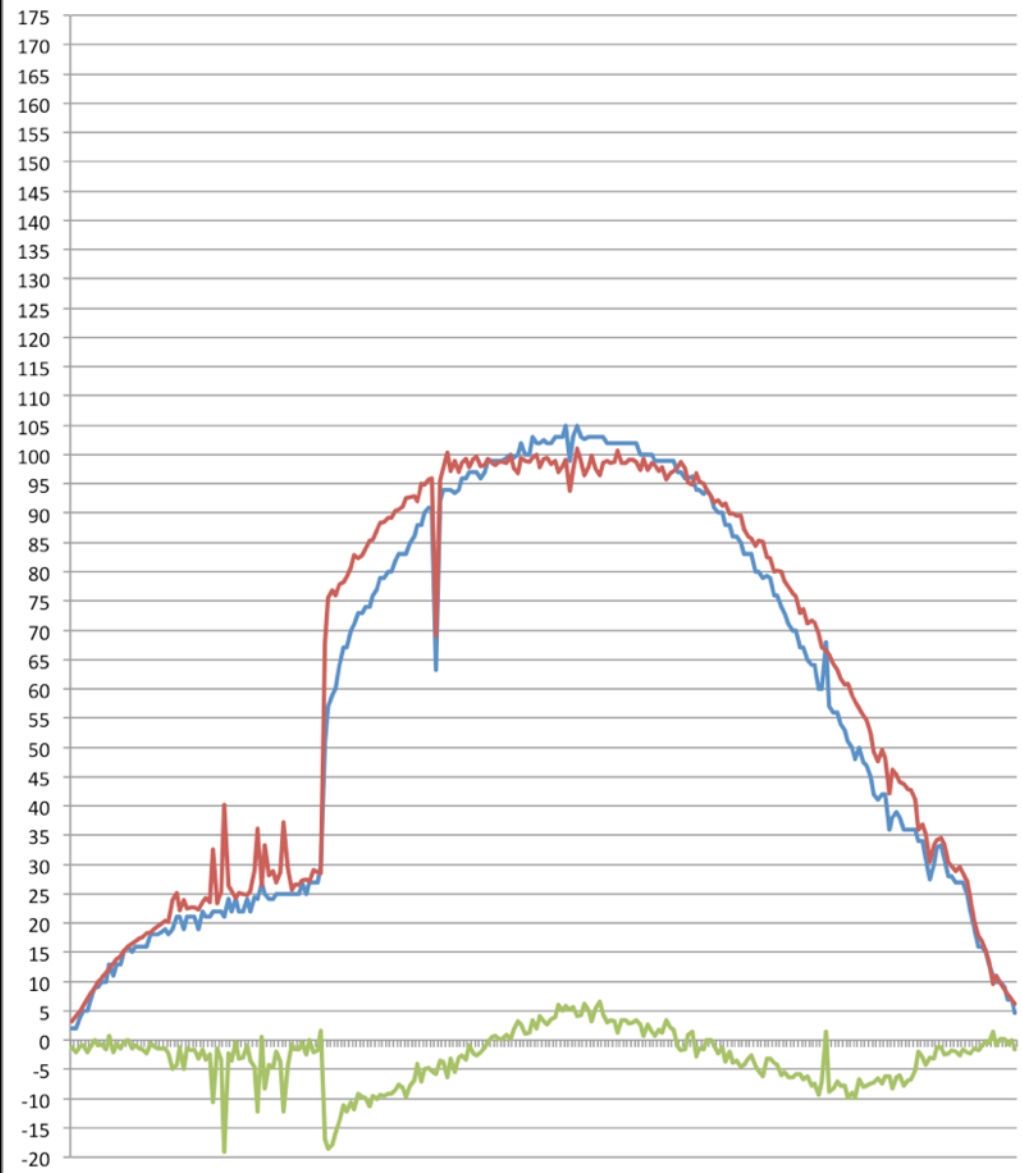
Camera Vertical - Facing South



# Camera Horizontal | Clear Sky



0700-1800  
MBE = -5%  
RSME= 11%



0700-1800  
MBE = 8%  
RSME= 13%

Rear Sensor

Front Sensor

# Camera Horizontal | Intermediate Sky



0600



0800



1000



1200



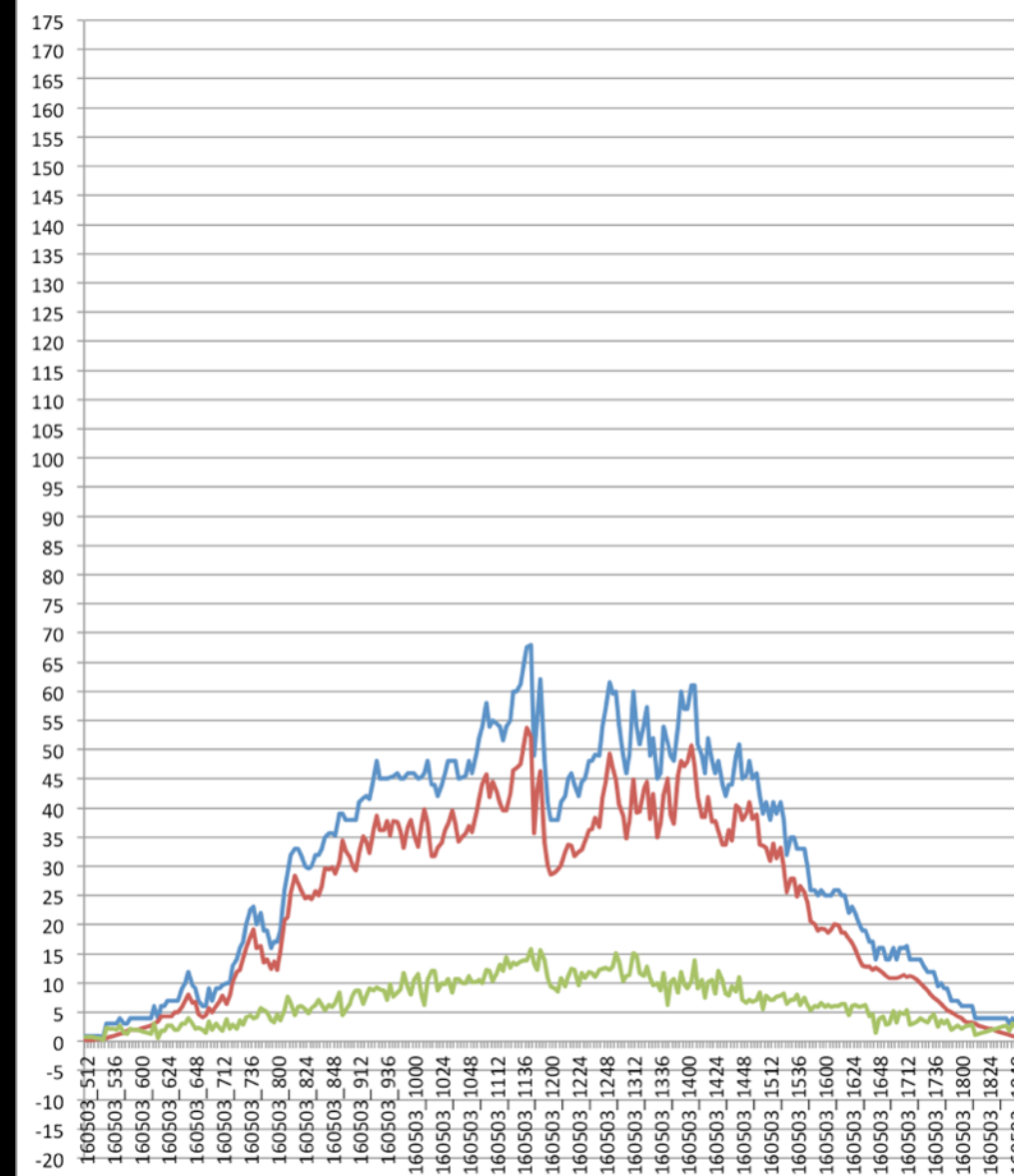
1400



1600



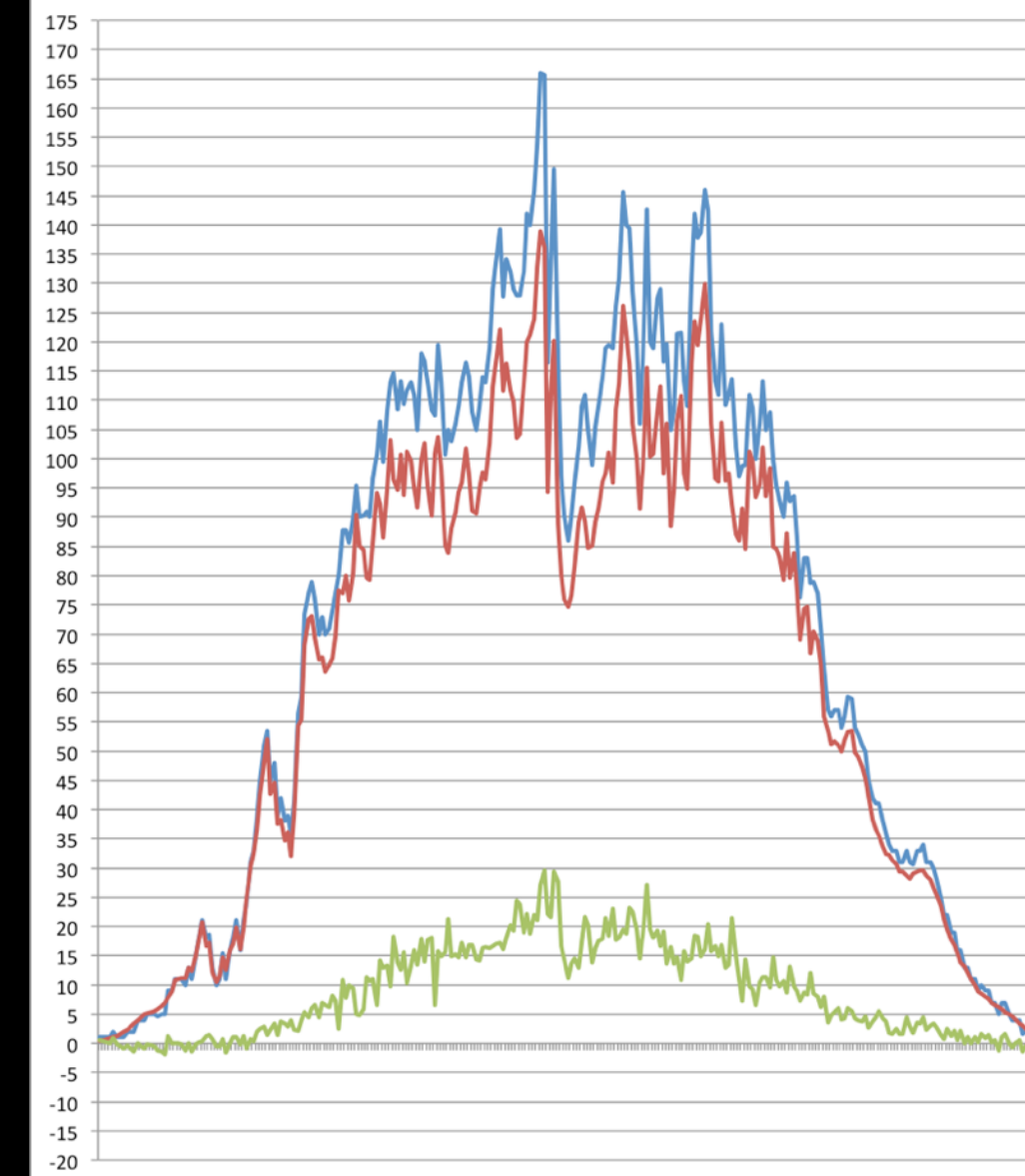
1800



0700-1800  
MBE = -22%  
RSME= 23%

Model Illum  
HDR Illum  
Diff Model-HDR

Rear Sensor



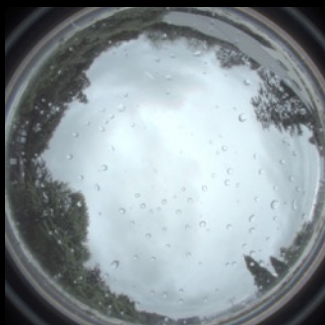
0700-1800  
MBE = -11%  
RSME= 12%

Model Illum  
HDR Illum  
Diff Model-HDR

Front Sensor



# Camera Horizontal | Overcast Sky



0600



0800



1000



1200



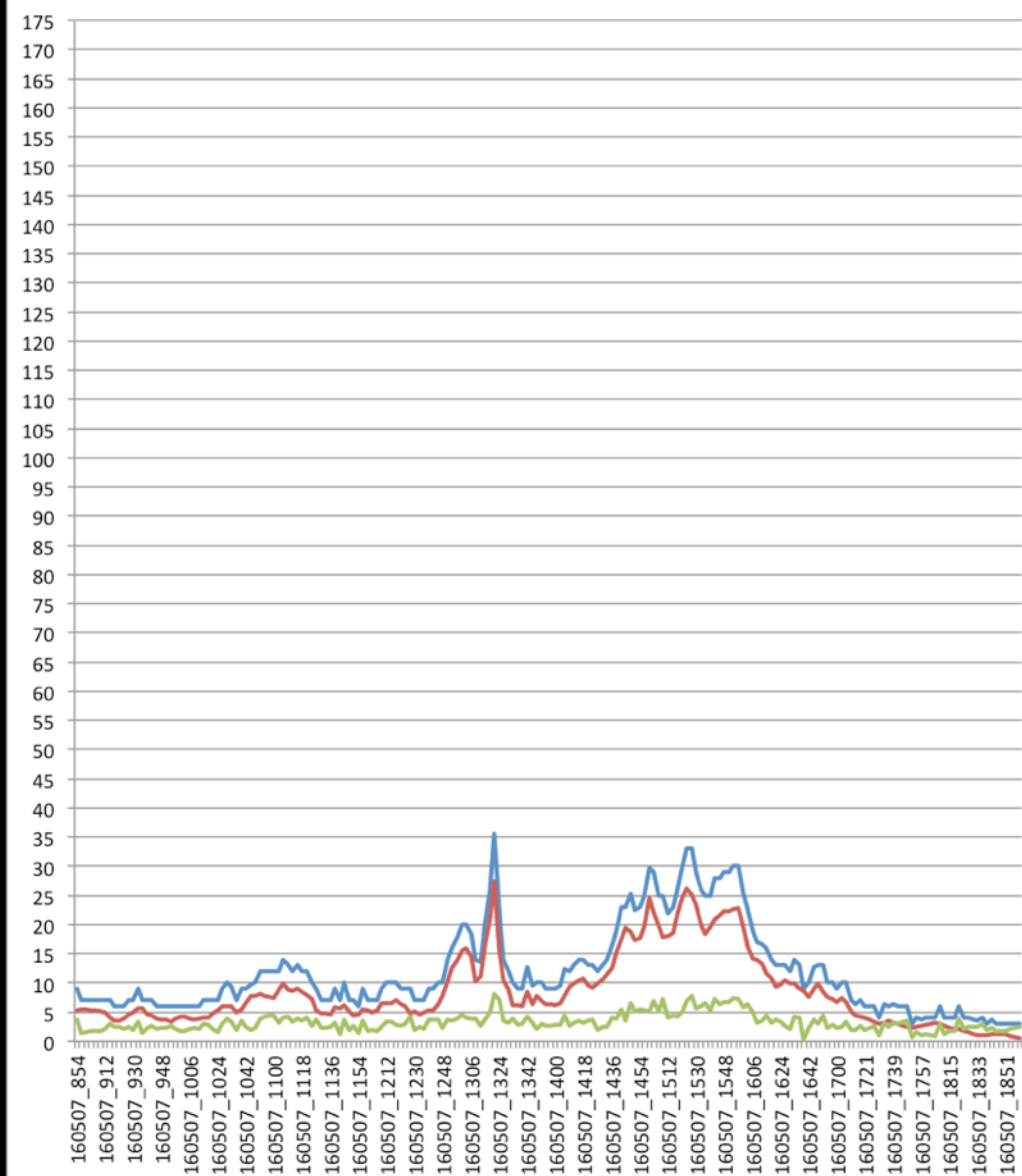
1400



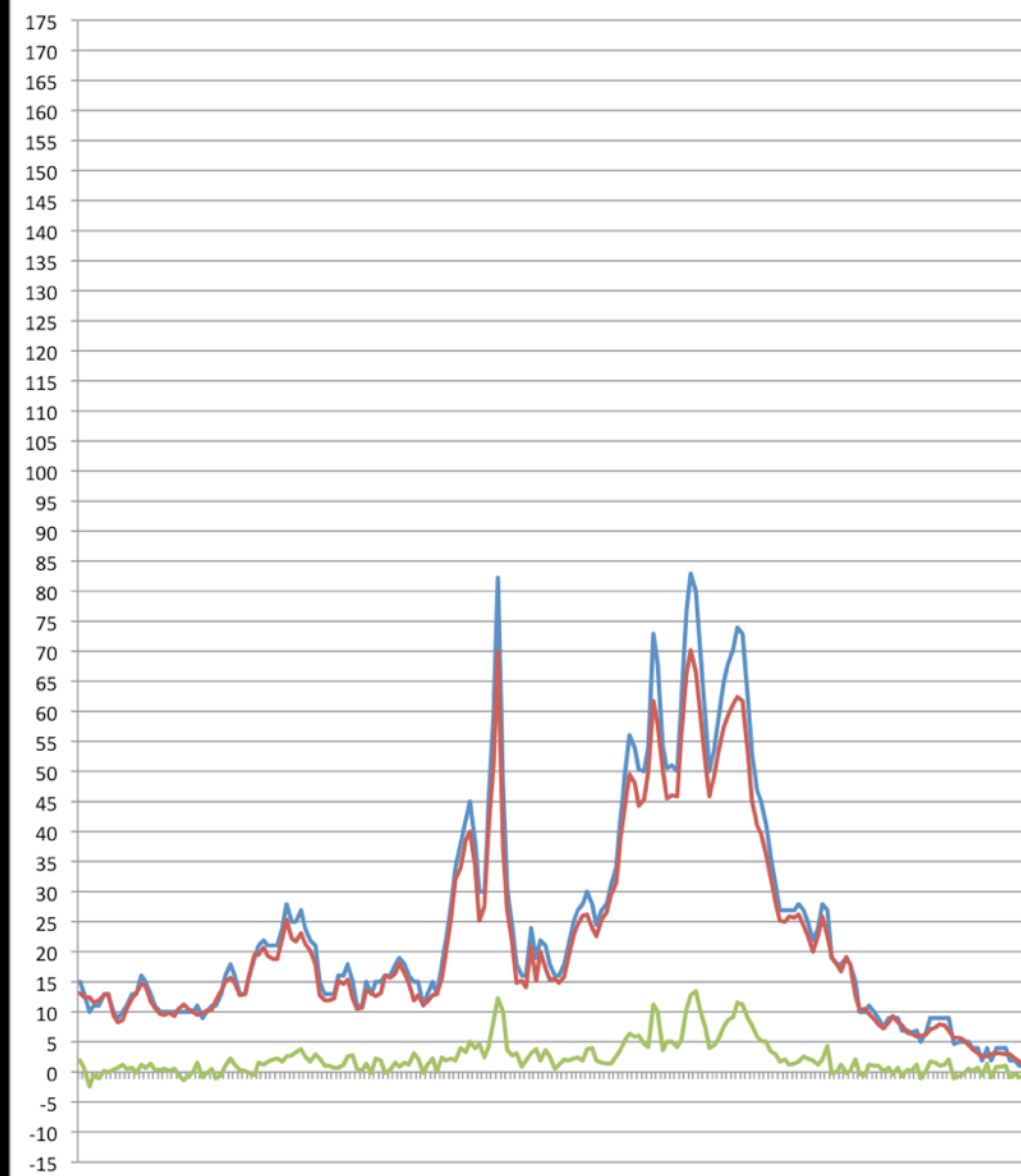
1600



1800



0700-1800  
MBE = -29%  
RSME= 30%

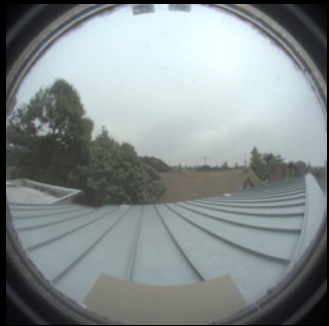


0700-1800  
MBE = -7%  
RSME= 10%

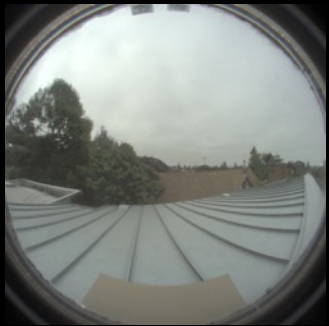
Rear Sensor

Front Sensor

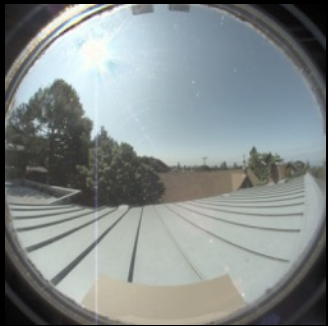
Camera Vertical | Clear Sky



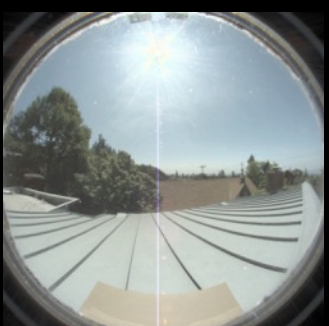
0600



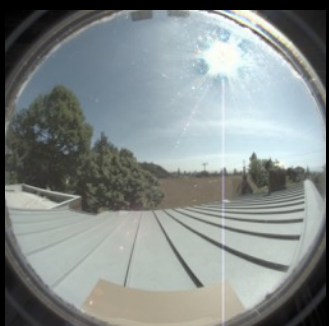
0800



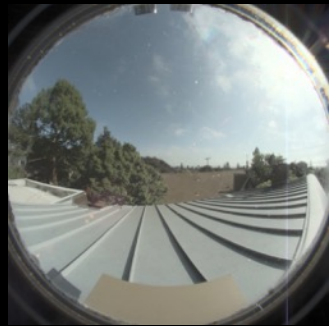
1000



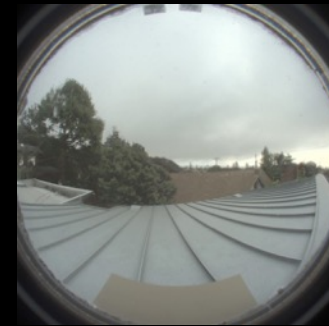
1200



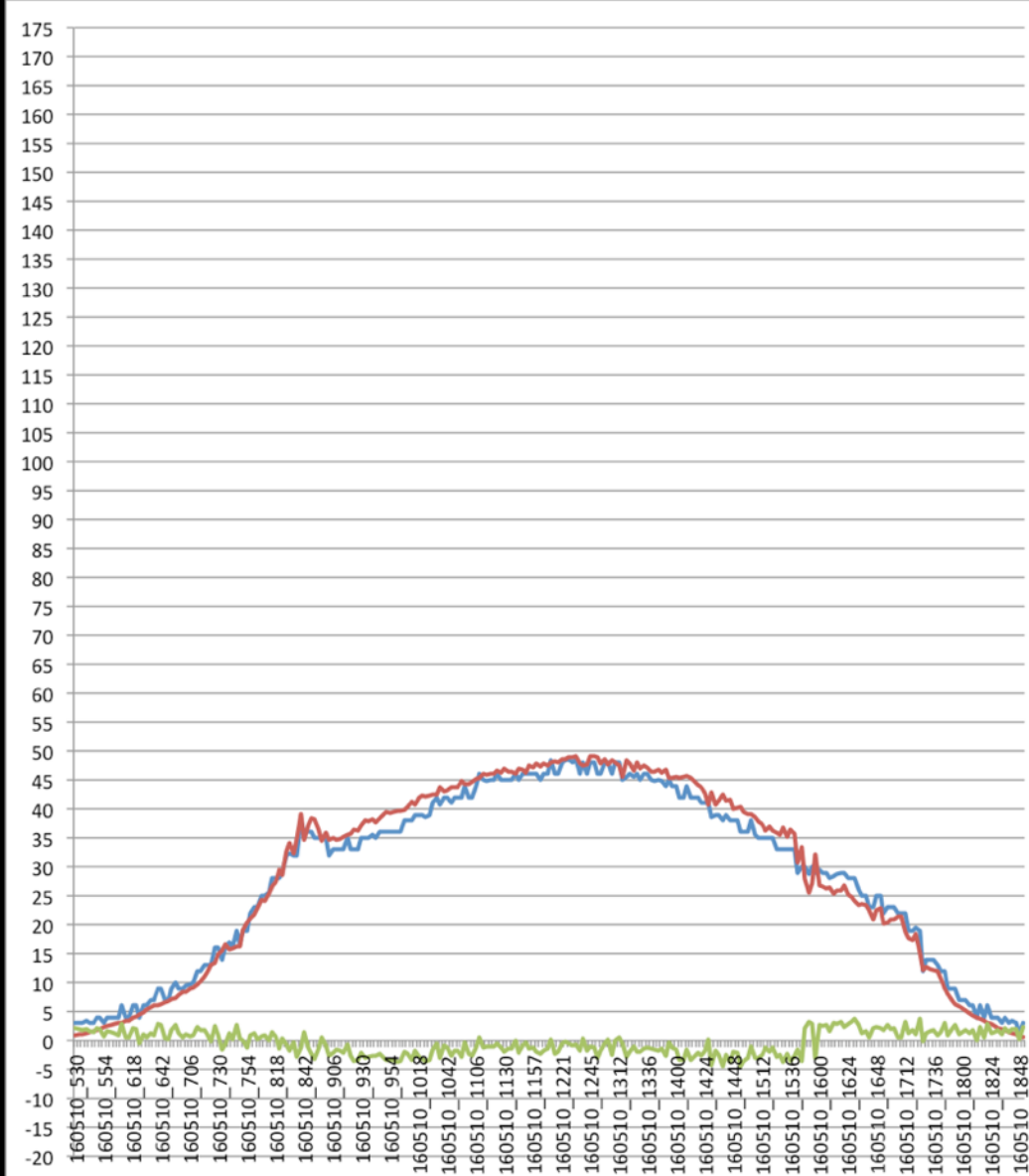
1400



1600



1800



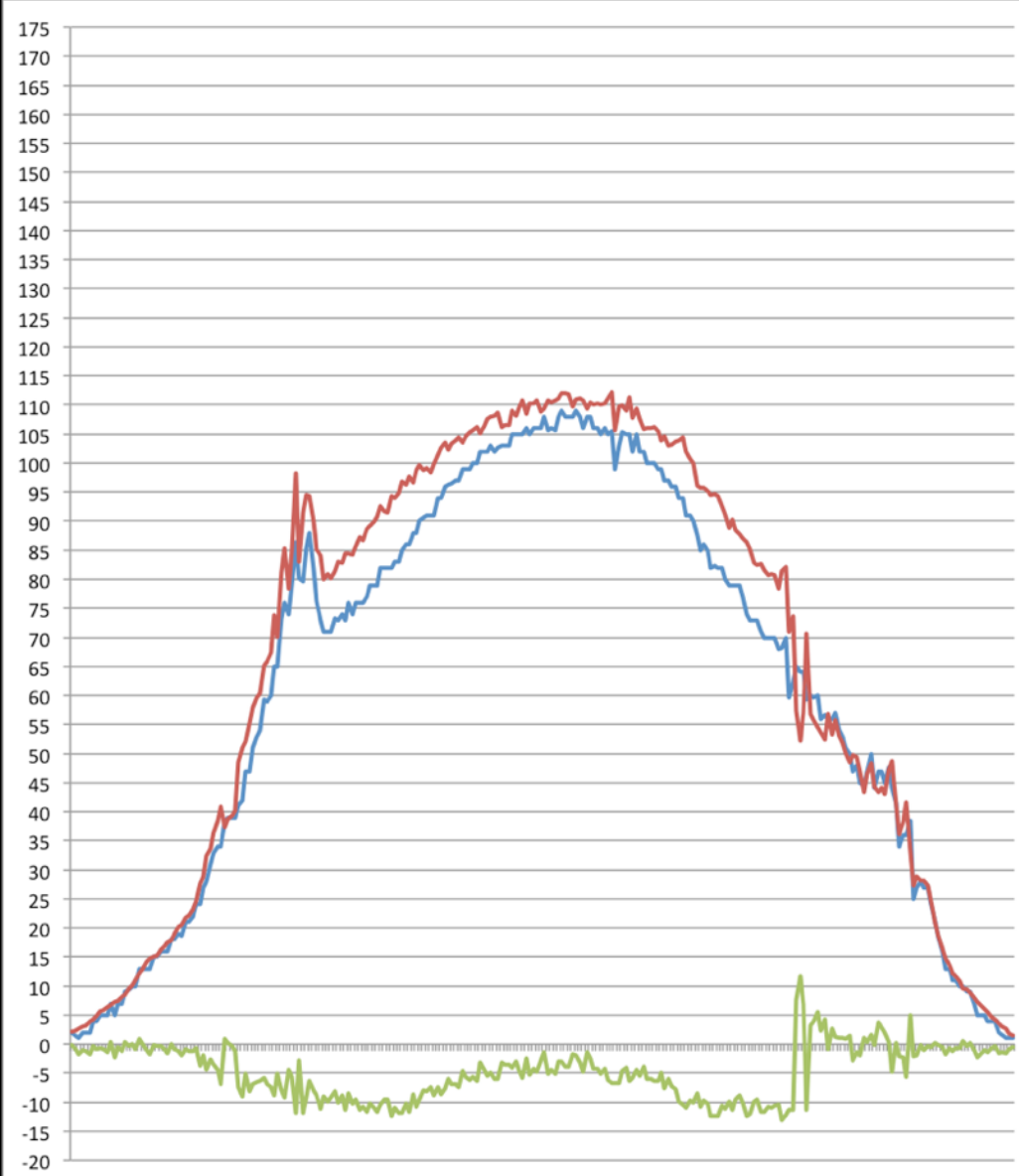
0700-1800

MBE = 1%

RSME= 8%

Model Illum  
HDR Illum  
Diff Model-HDR

Rear Sensor



0700-1800

MBE = 7%

RSME= 10%

Model Illum  
HDR Illum  
Diff Model-HDR

Front Sensor



# Camera Vertical | Intermediate Sky



0600



0800



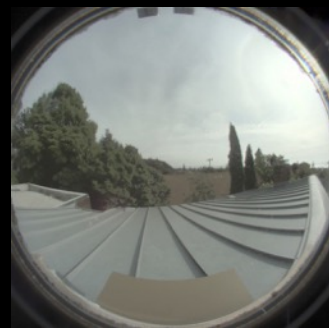
1000



1200



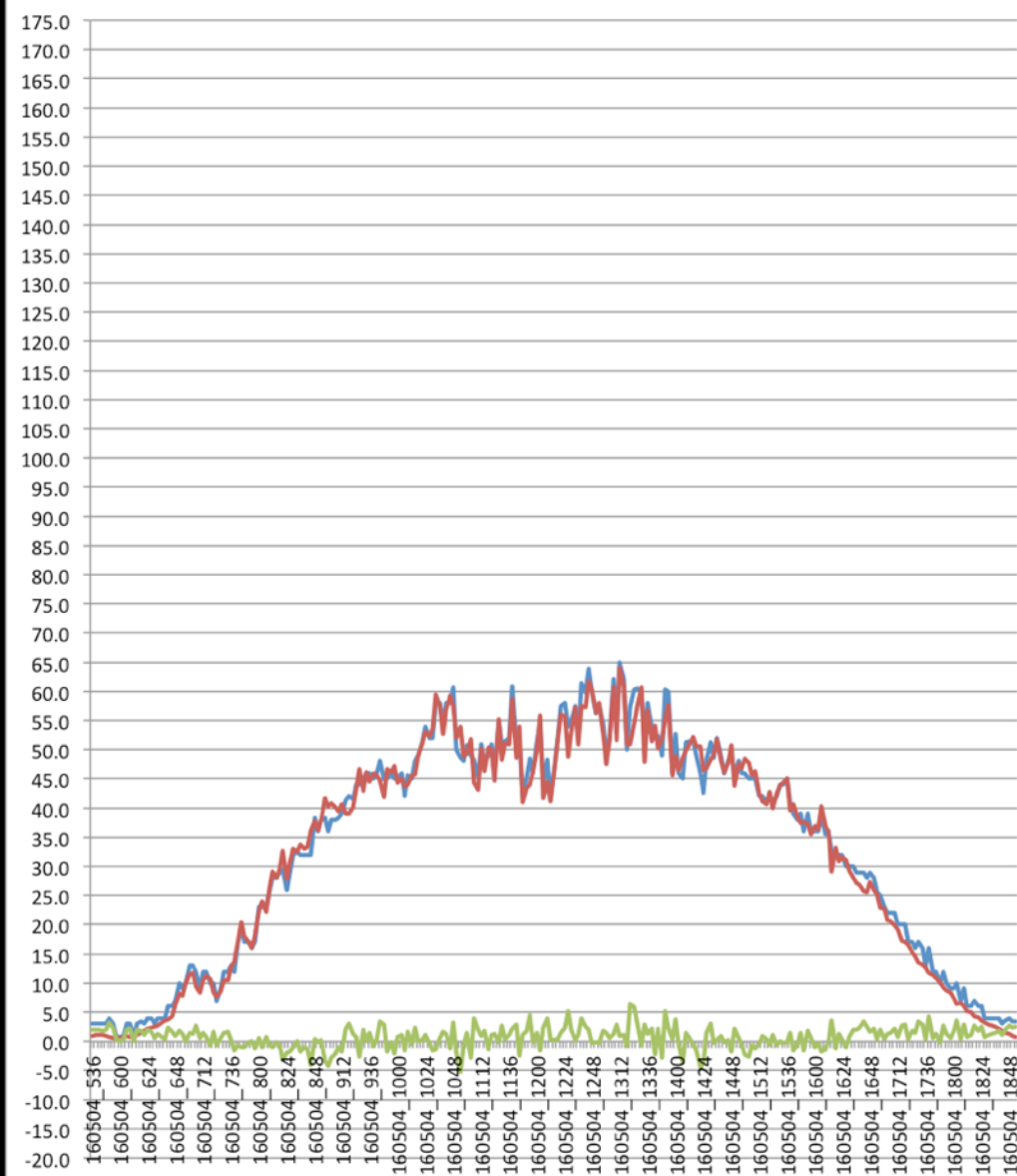
1400



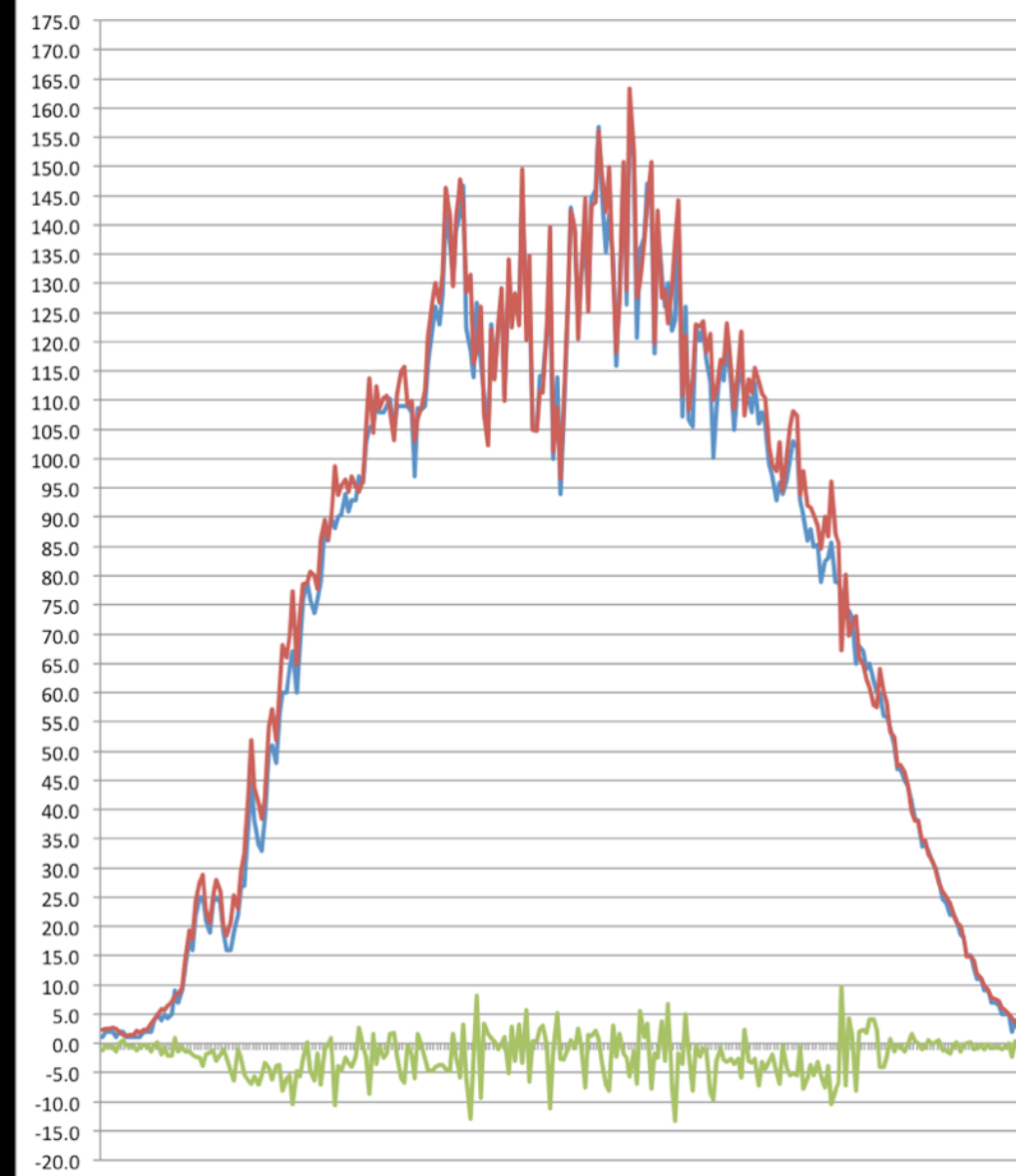
1600



1800



Rear Sensor



Front Sensor

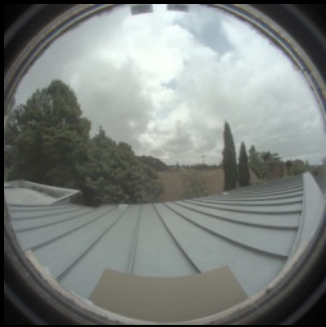
# Camera Vertical | Overcast Sky



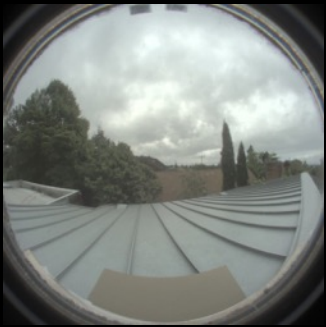
0600



0800



1000



1200



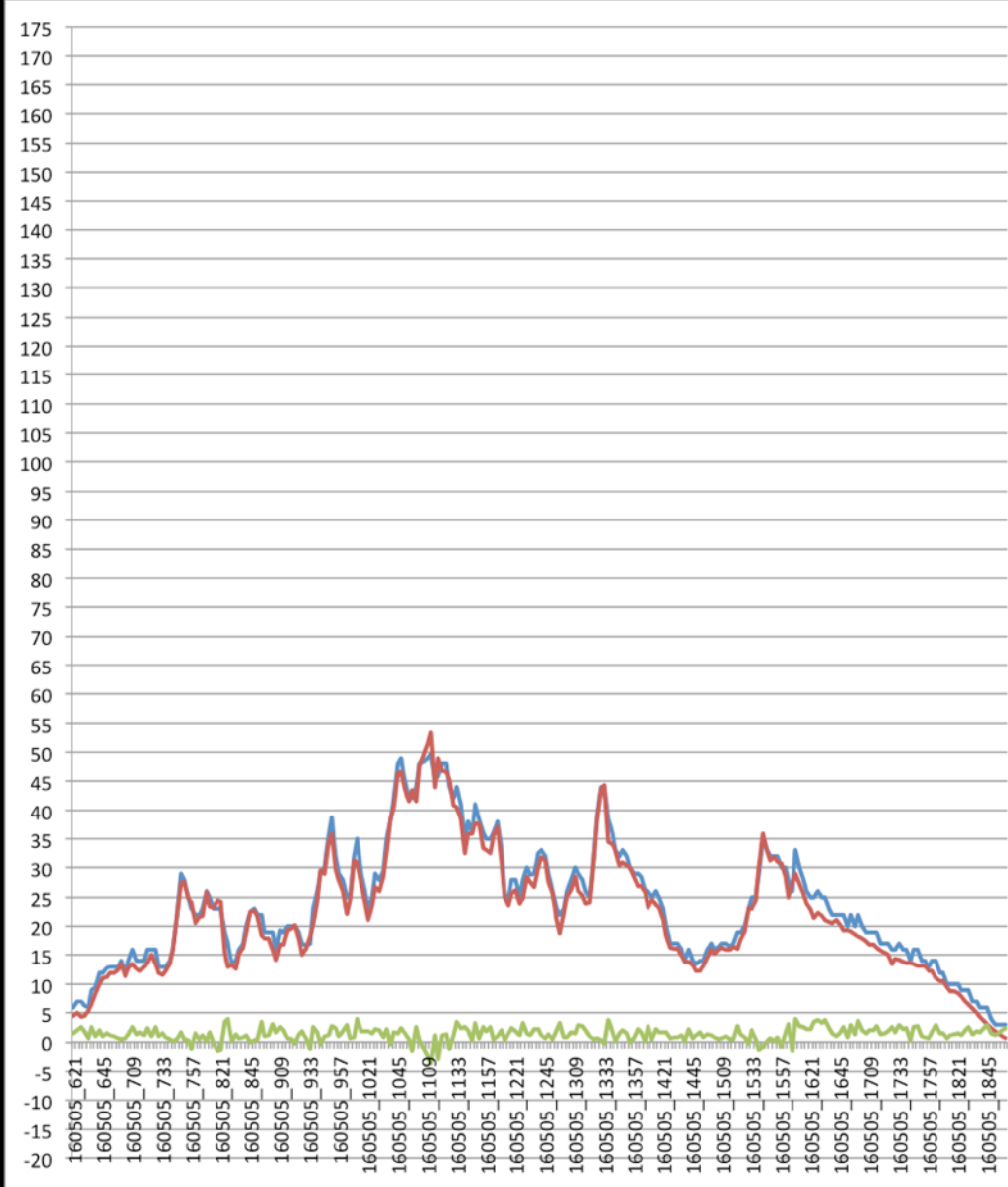
1400



1600

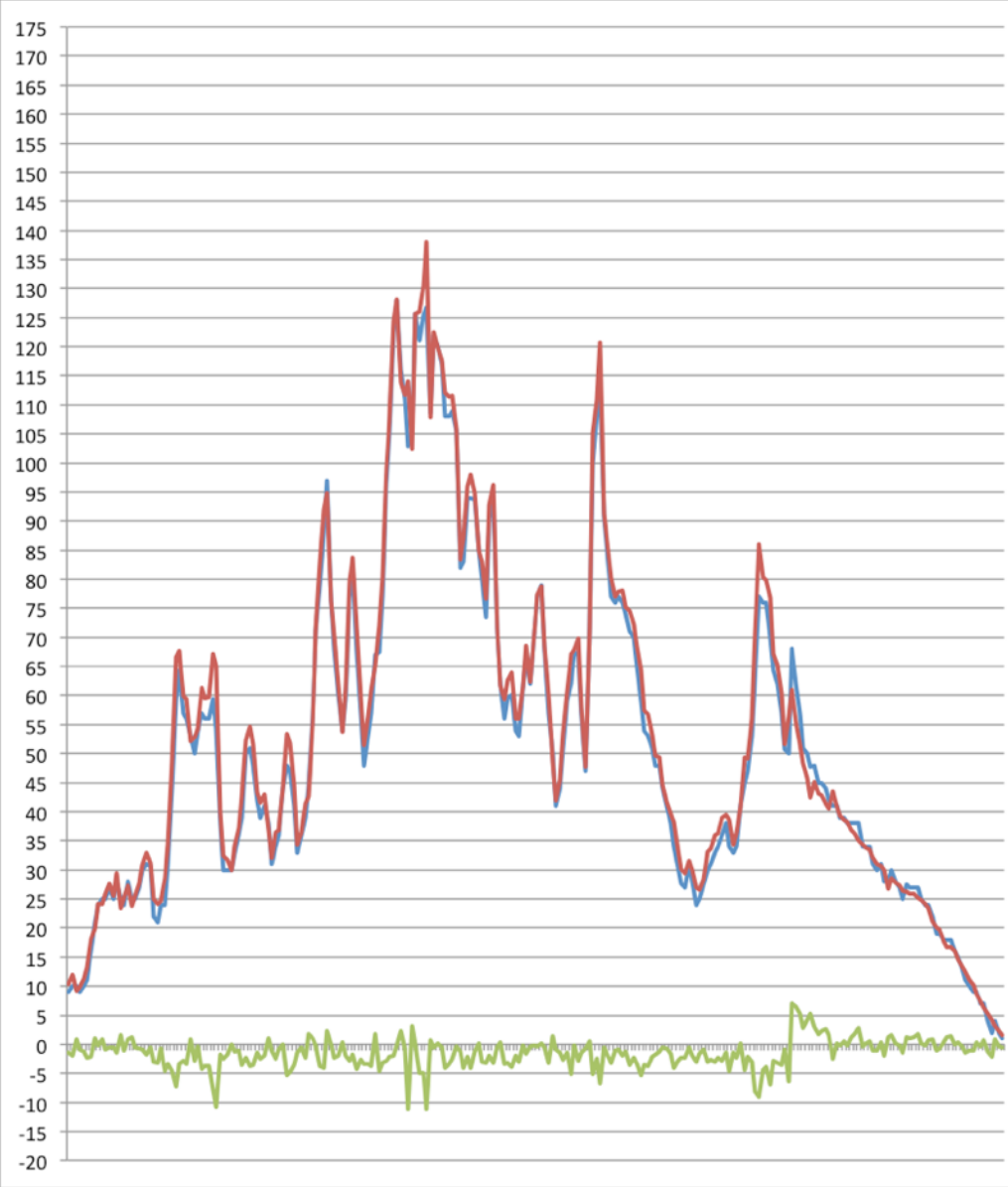


1800



0700-1800  
MBE = -6%  
RSME= 8%

Model Illum  
HDR Illum  
Diff Model-HDR



0700-1800  
MBE = 3%  
RSME= 6%

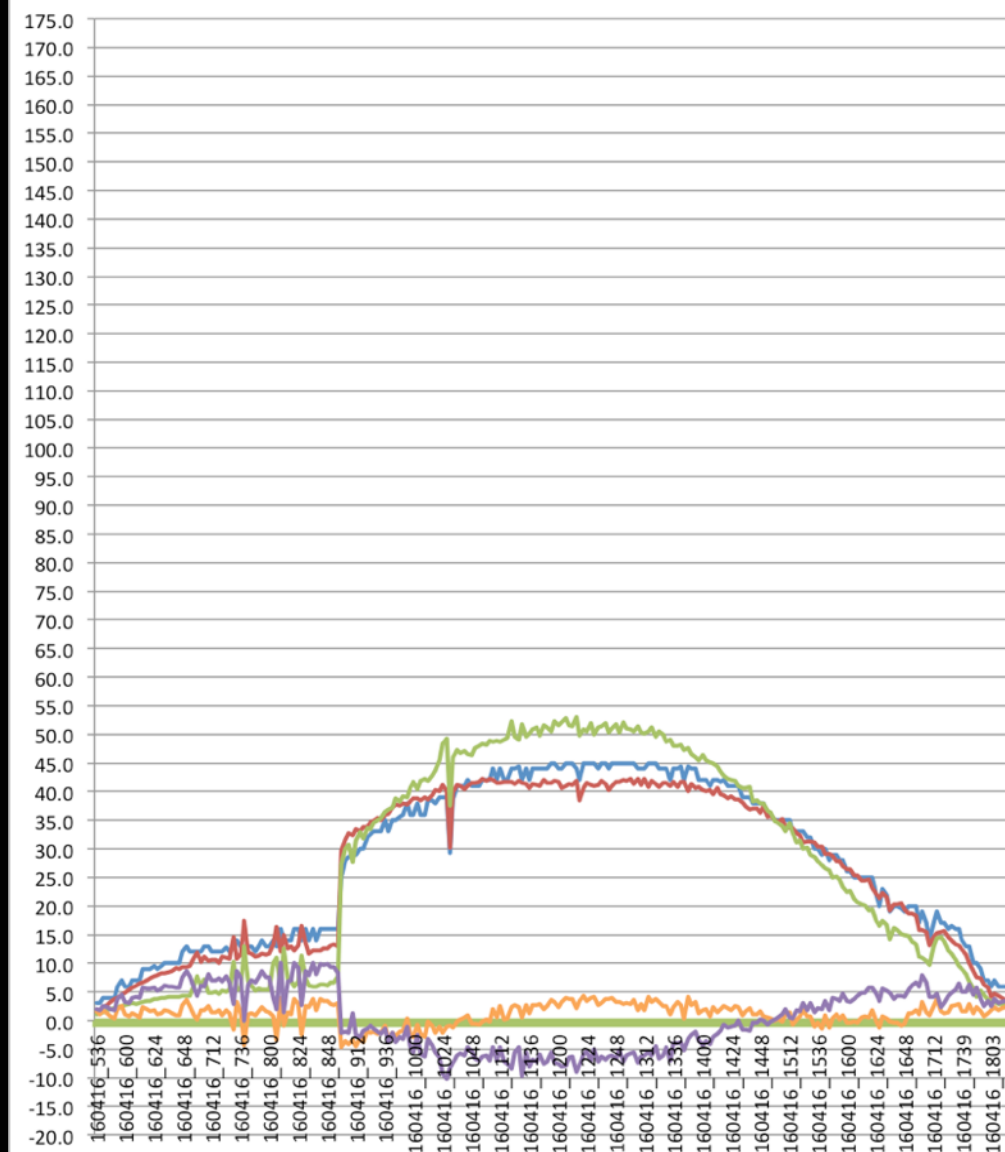
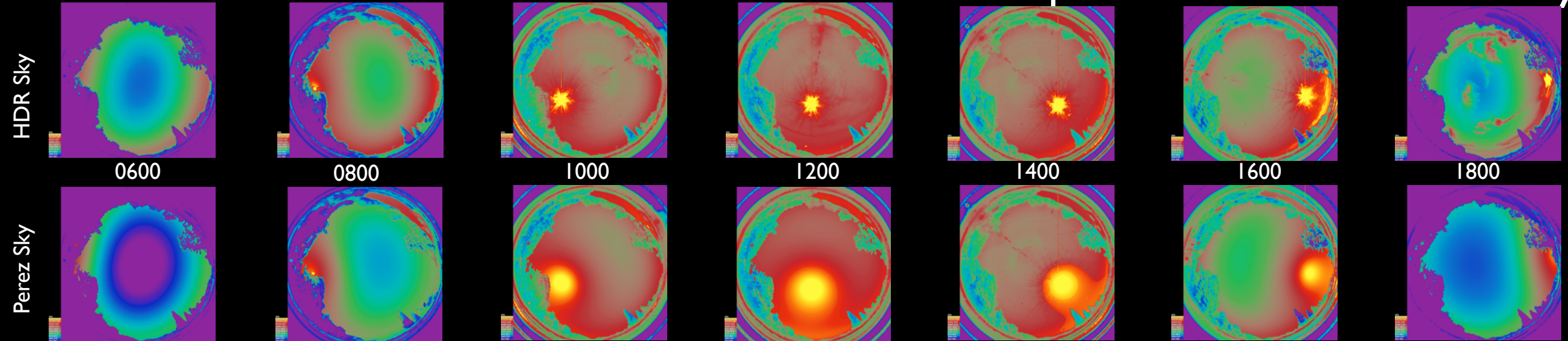
Model Illum  
HDR Illum  
Diff Model-HDR

Rear Sensor

Front Sensor



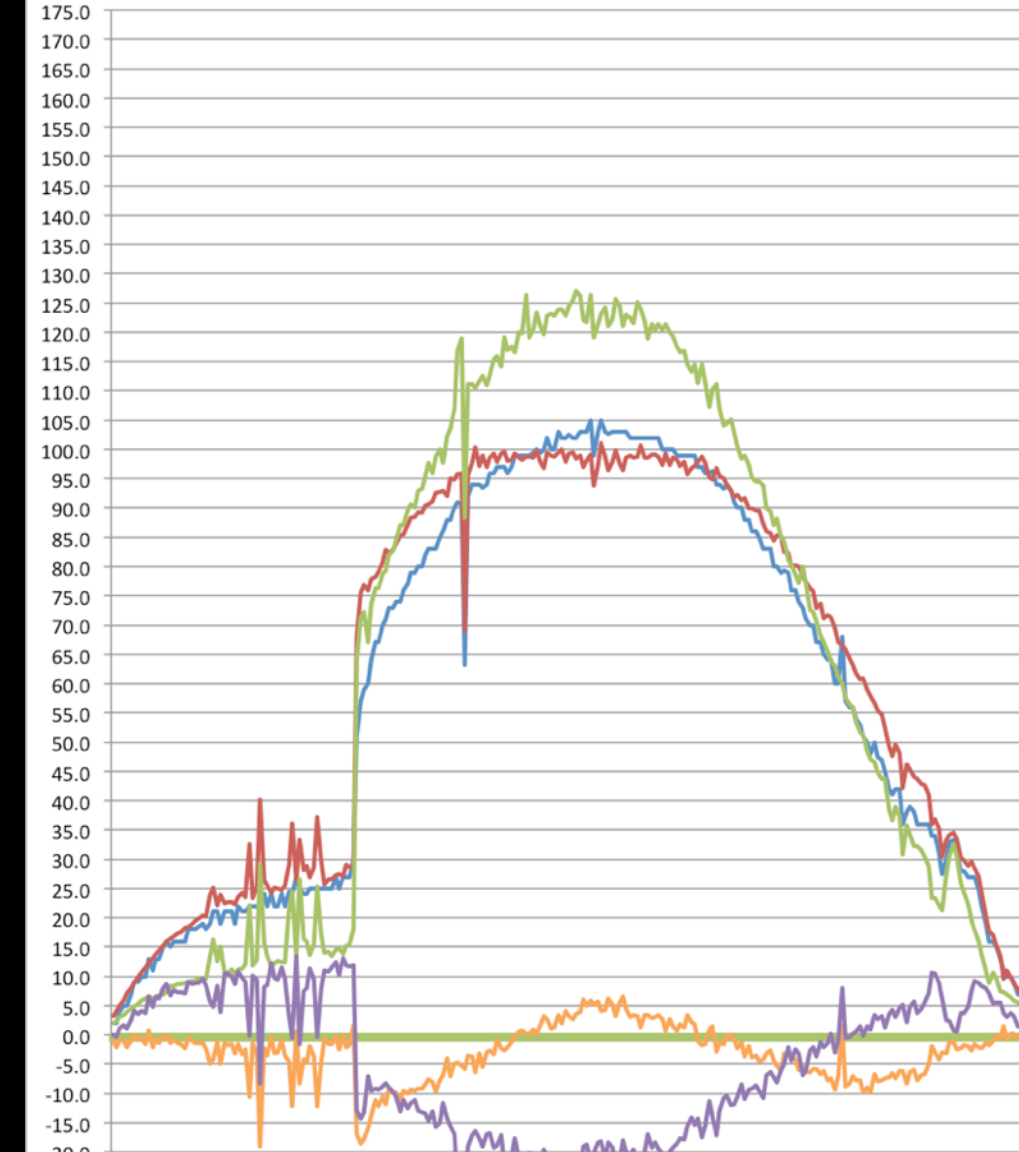
# Camera Horizontal | HDR + Perez Clear Sky



0700-1800  
HDR Sky  
MBE = -5%  
RSME= 11%  
Perez Sky  
MBE= -13%  
RSME= 32%

— Model Illum  
— HDR Illum  
— Perez Illum  
— Diff Model-HDR  
— Diff Model-Perez

Rear Sensor



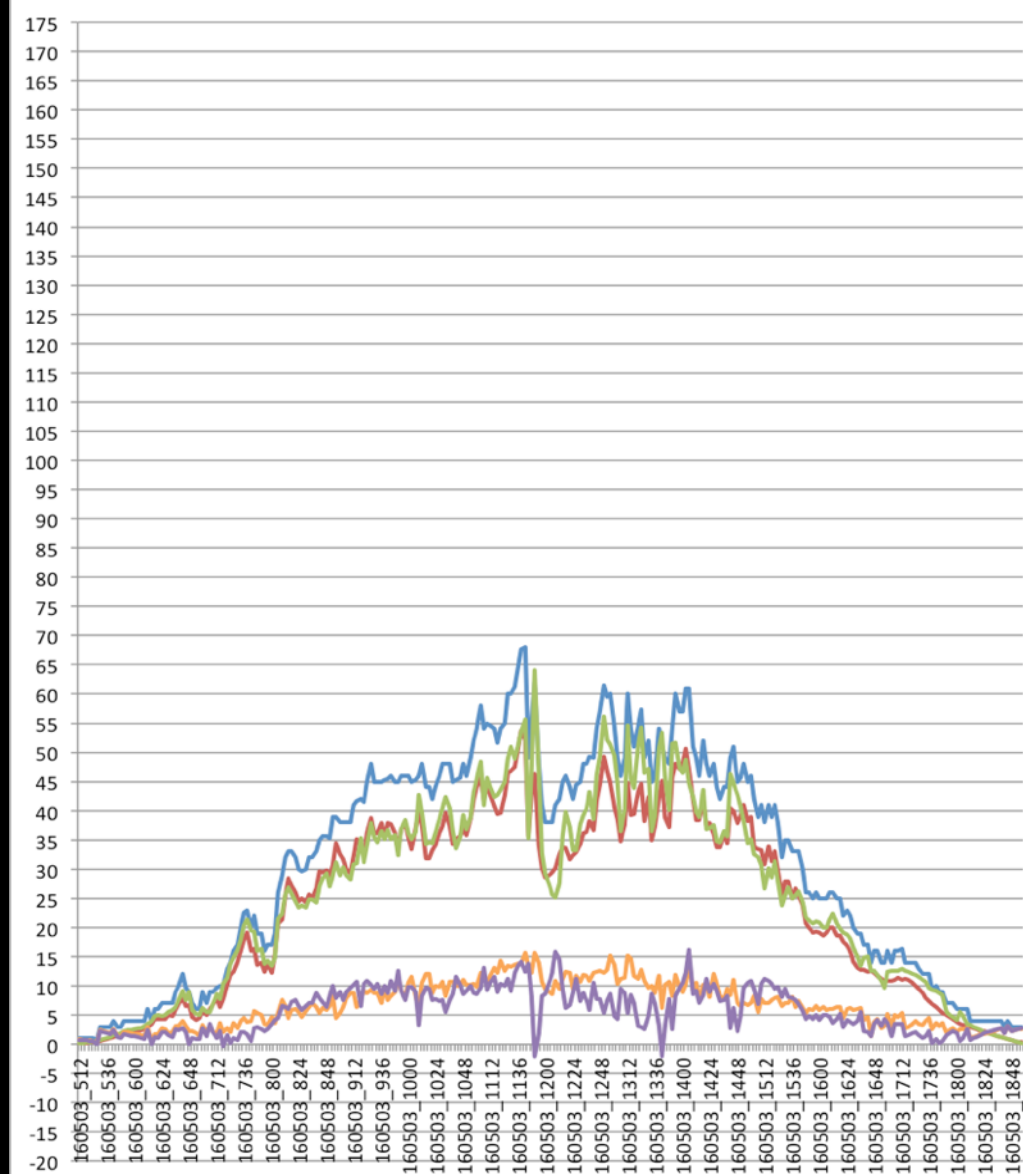
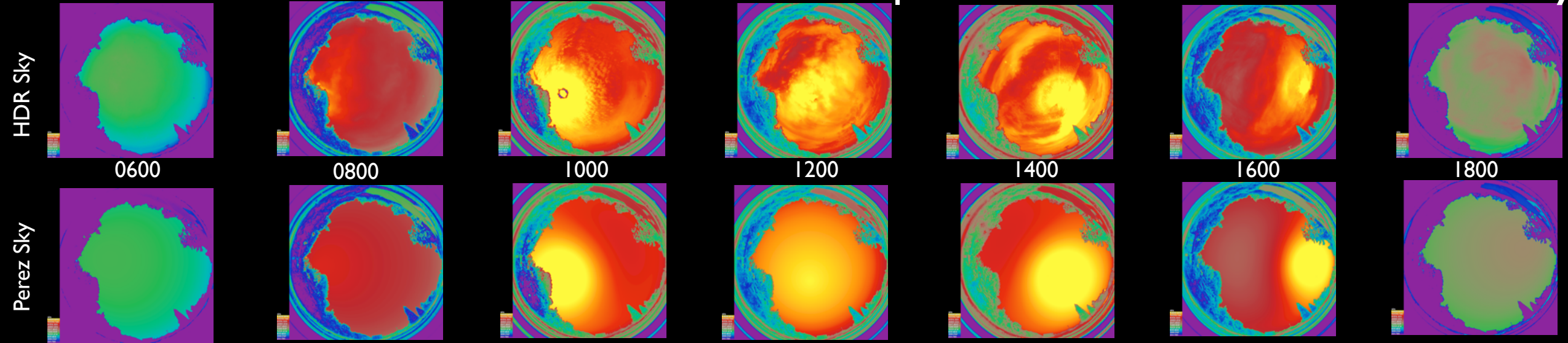
0700-1800  
HDR Sky  
MBE = 8%  
RSME= 13%  
Perez Sky  
MBE= -3%  
RSME= 26%

— Model Illum  
— HDR Illum  
— Perez Illum  
— Diff Model-HDR  
— Diff Model-Perez

Front Sensor



# Camera Horizontal | HDR + Perez Intermediate Sky



Rear Sensor

0700-1800

*HDR Sky*

MBE = -22%

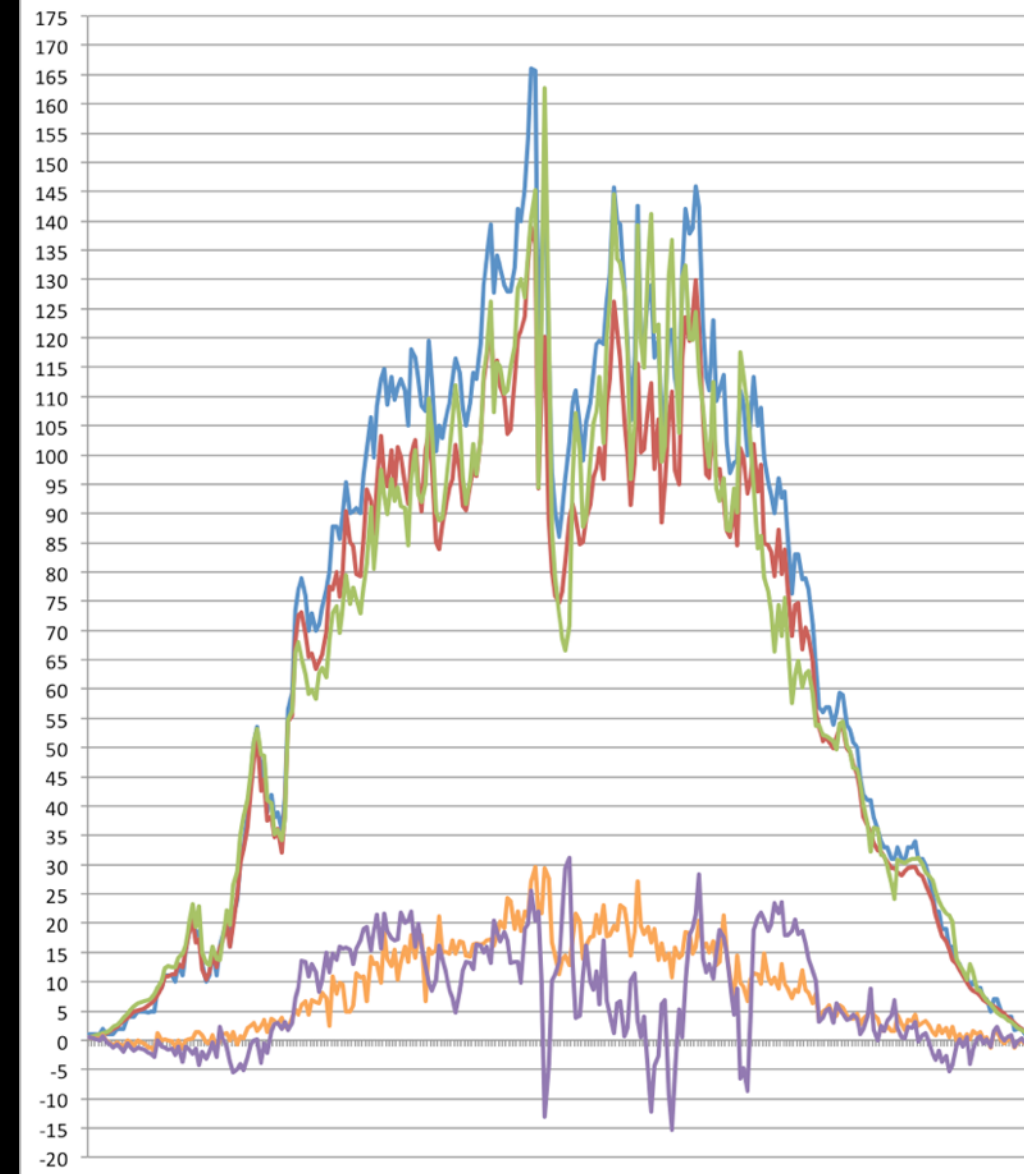
RSME= 23%

*Perez Sky*

MBE= -18%

RSME= 19%

Model Illum  
HDR Illum  
Perez Illum  
Diff Model-HDR  
Model-Perez



Front Sensor

0700-1800

*HDR Sky*

MBE = -11%

RSME= 12%

*Perez Sky*

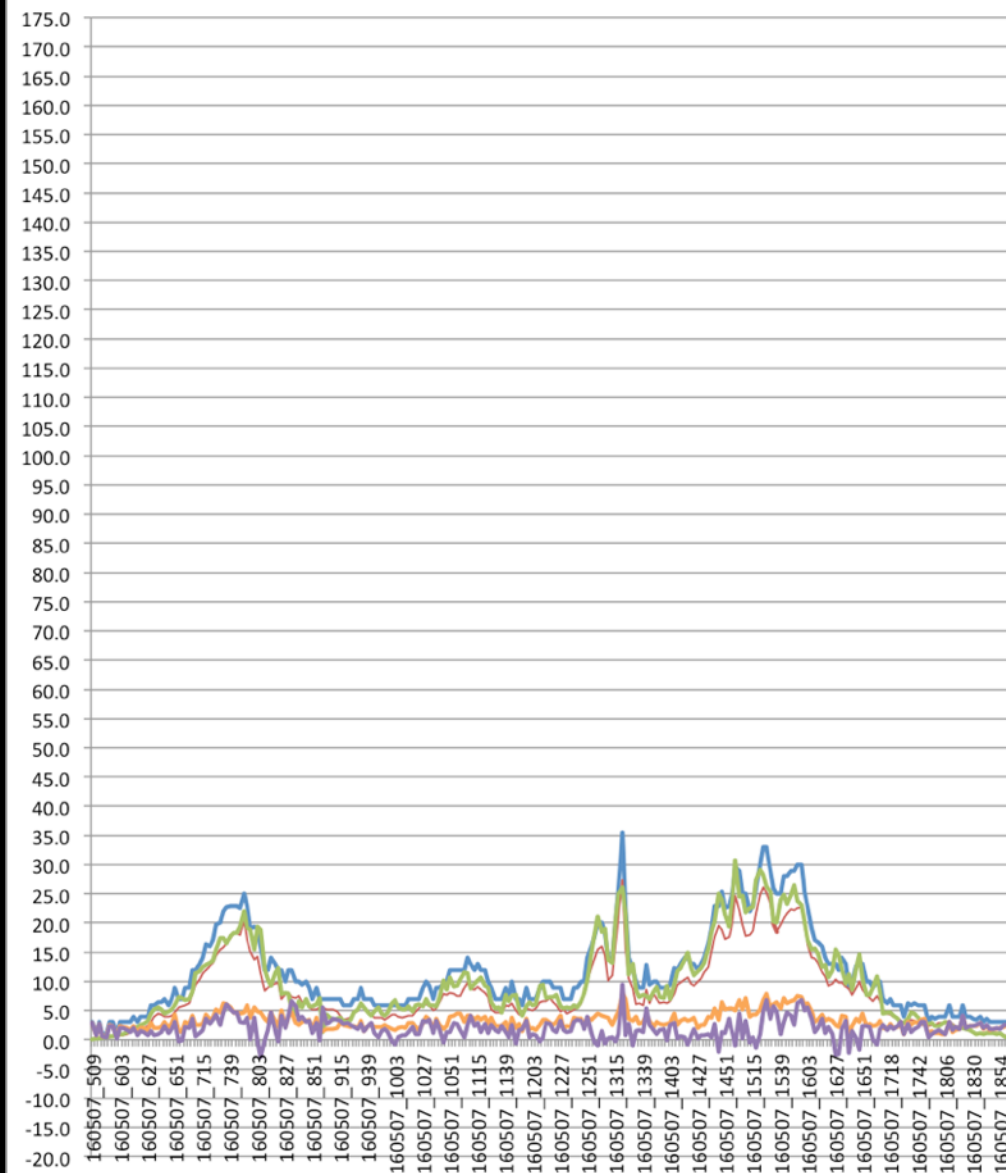
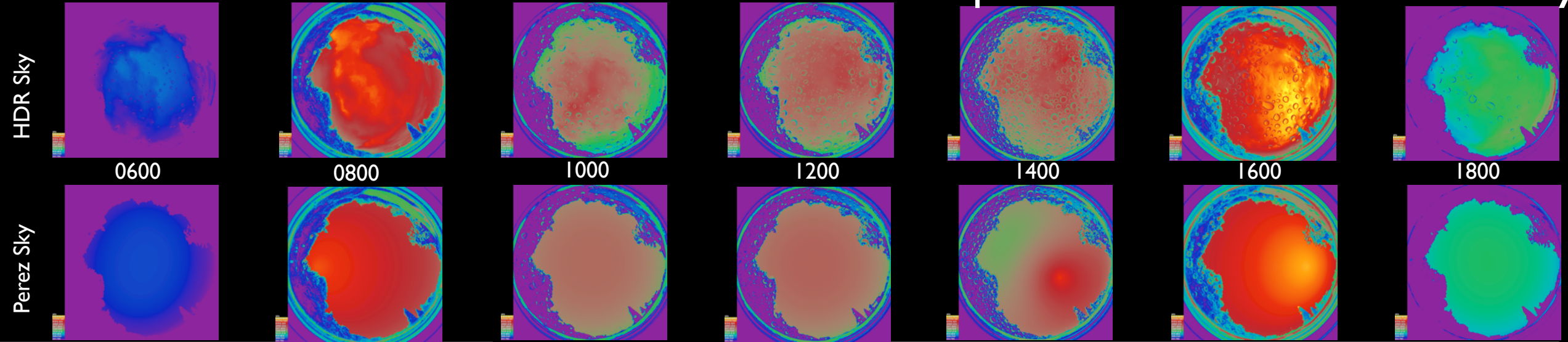
MBE= -8%

RSME= 14%

Model Illum  
HDR Illum  
Perez Illum  
Diff Model-HDR  
Model-Perez



# Camera Horizontal | HDR + Perez Overcast Sky



Rear Sensor

0700-1800

*HDR Sky*

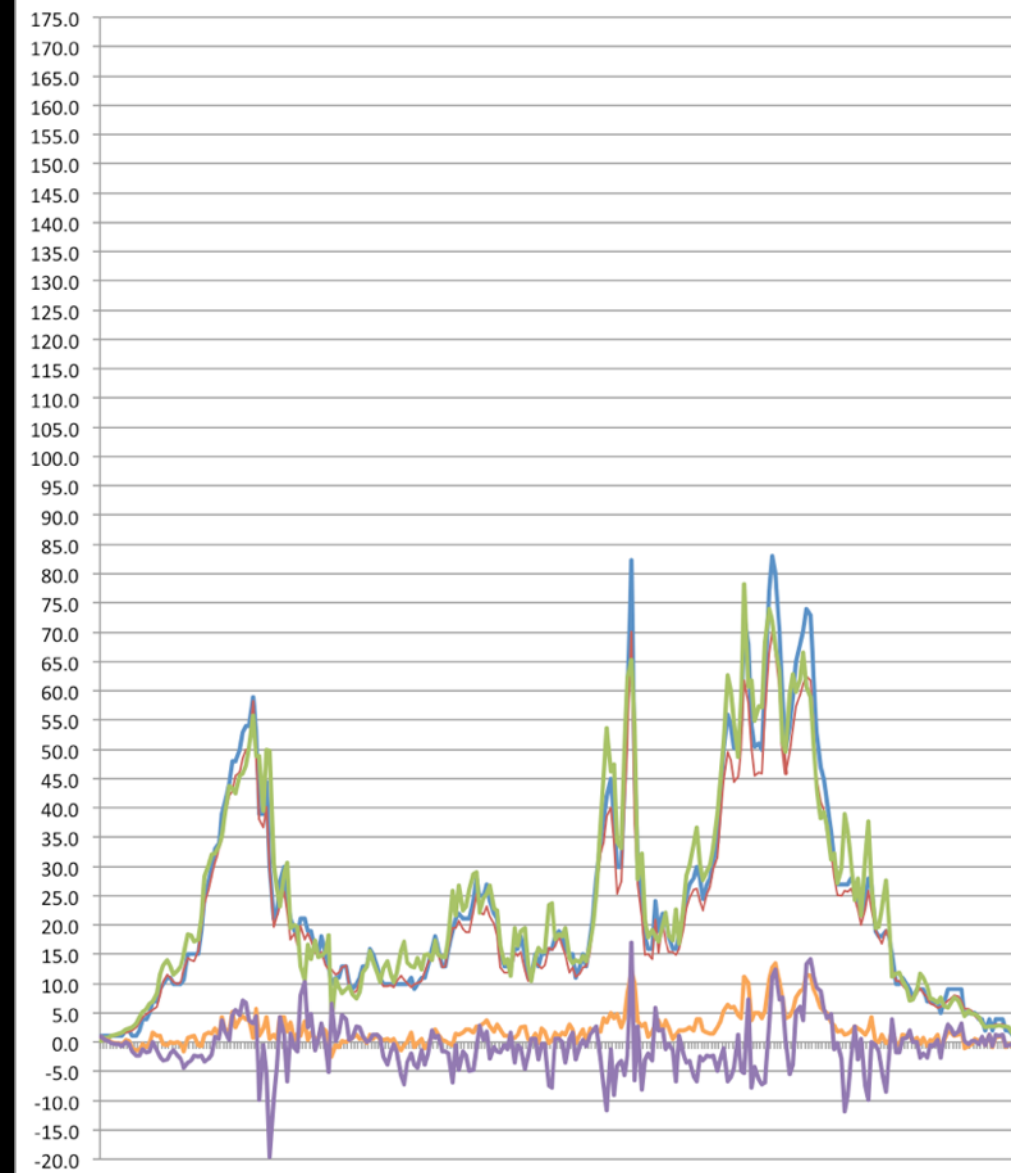
*MBE = -29%*

*RSME = 30%*

*Perez Sky*

*MBE = -18%*

*RSME = 24%*



Front Sensor

0700-1800

*HDR Sky*

*MBE = -7%*

*RSME = 10%*

*Perez Sky*

*MBE = 6%*

*RSME = 20%*



# Camera Horizontal | Clear Sky (Daylight Coefficients)



0600



0800



1000



1200



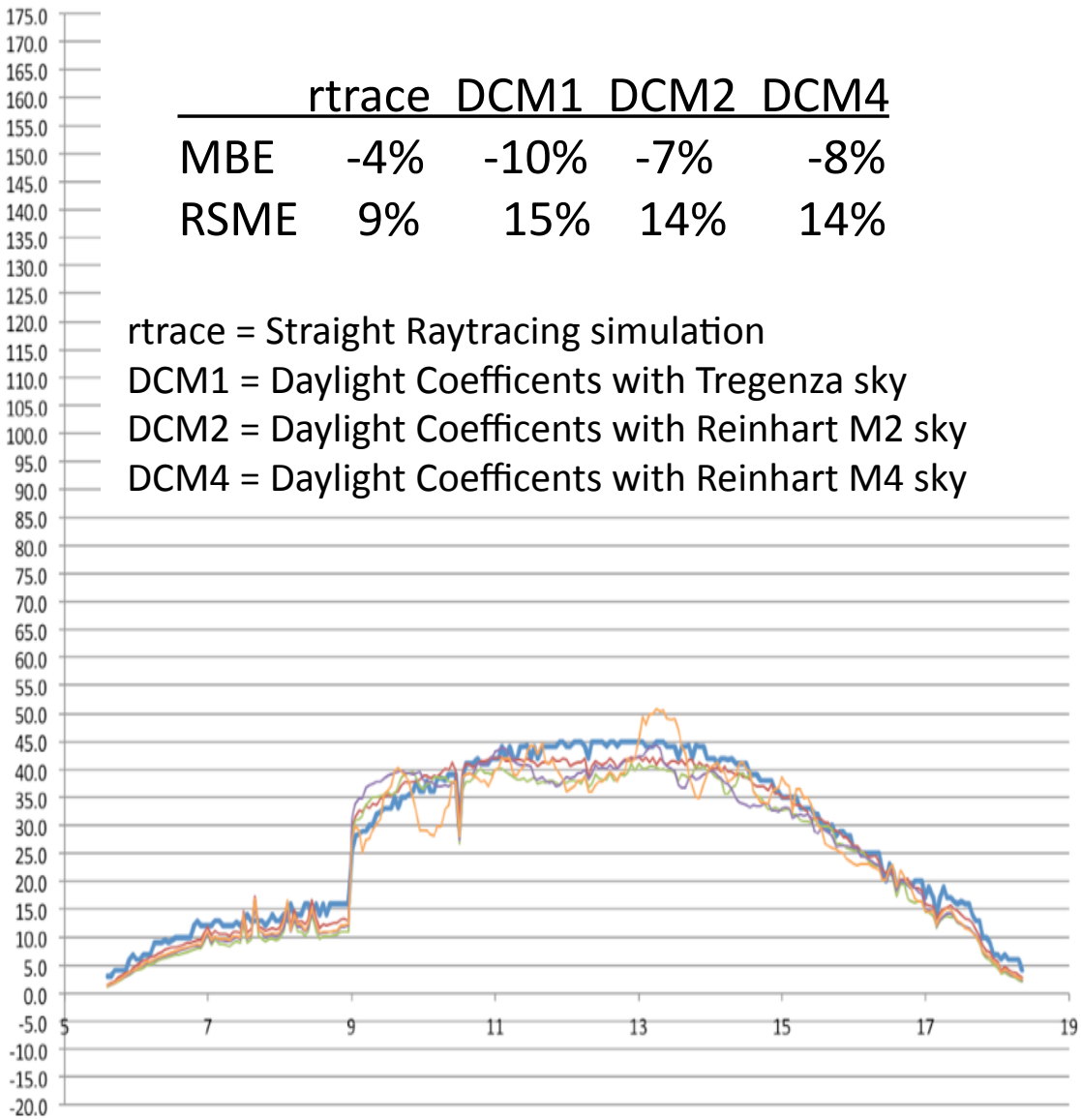
1400



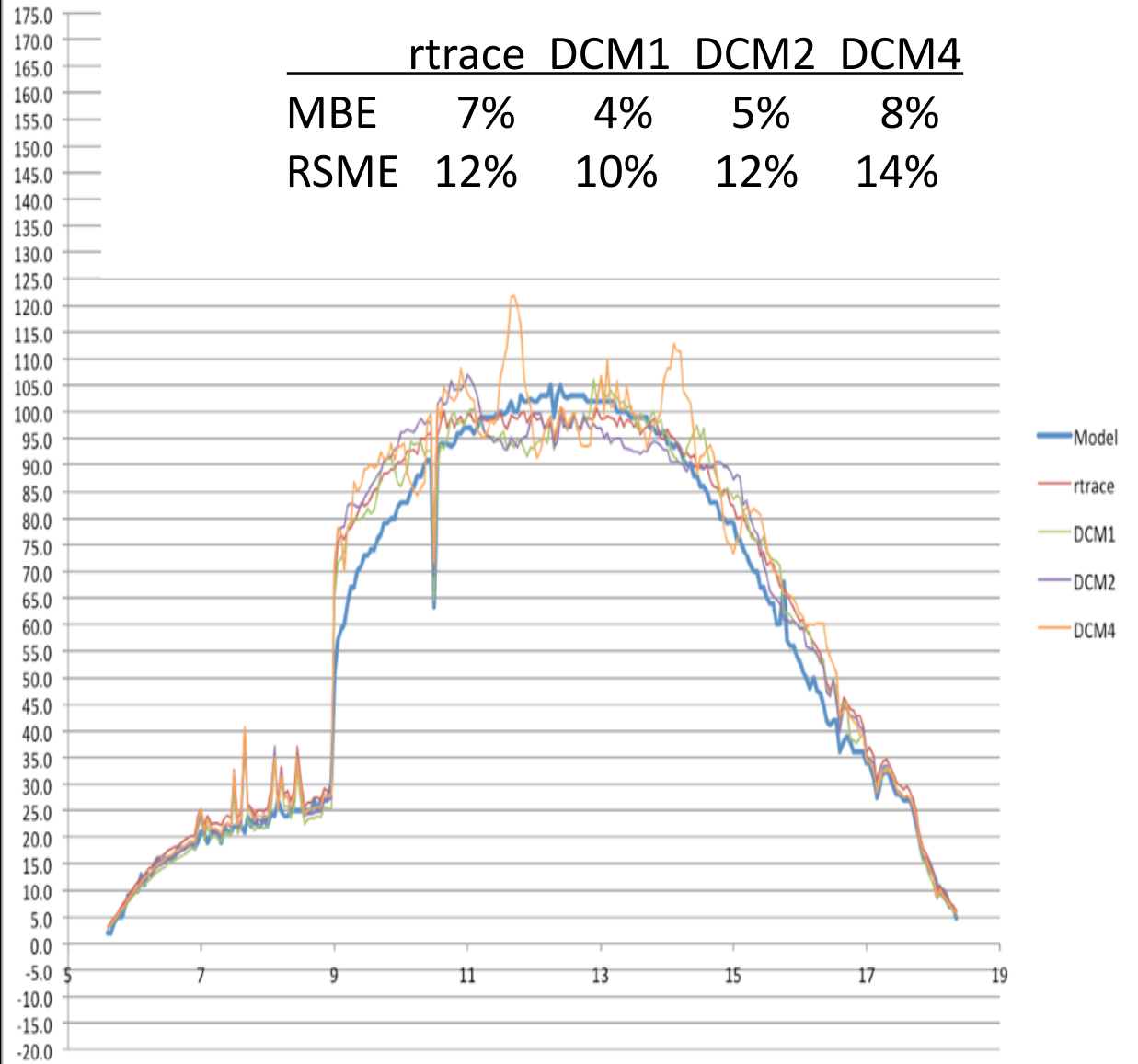
1600



1800



Rear Sensor



Front Sensor



# ***Thank You!!***

Chris Humann  
chris@terrestriallight.com



For HDR Skylimages taken from atop of Lawrence Berkeley National Lab's FlexLab:  
<http://flexskycam.lbl.gov/>