GSEP'S Cool Roofs and Pavements Working Group | 2012

Global Climate Benefits of Cool Roof

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Earth System Cooling with Reflective Roofs

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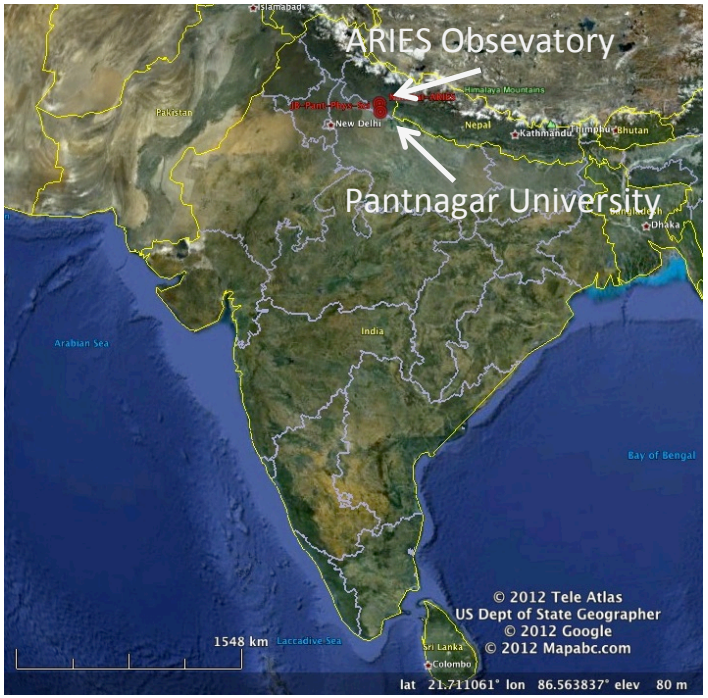

Acknowledgements

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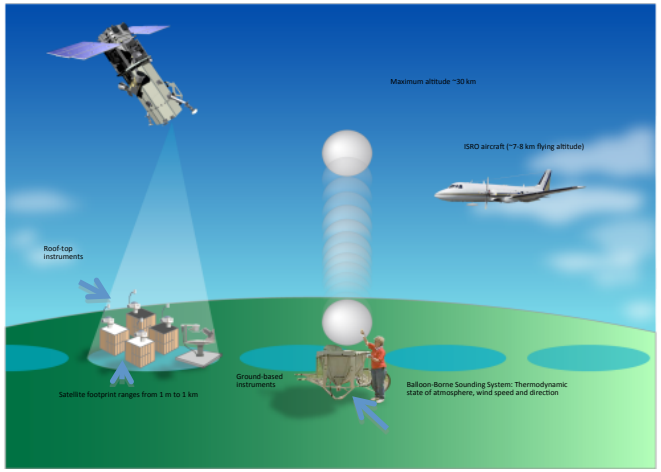
Earth System Cooling with Reflective Roofs

EERE/SC study verifies predicted global cooling benefit of white roofs in warm urban climates

- USDOE-Indian collaboration measured atmospheric radiation and building heat budgets at two sites in N. India, June 2011-March 2012

- Combination of satellite remote sensing, airborne, and surface measurements show
  1) Heat loads are reduced to buildings, improving indoor comfort for occupants of un-conditioned buildings in warm climates
  2) Radiative transfer models capture predicted benefit of white roofs



Original and White Coated Roofs

Introduction

Earlier work

- Menon et.al (2010)
  - Negative radiative forcing – 18.2 W/m^2 for 0.1 increase in Albedo
  - uncoupled global land surface model
- Millstein et.al (2011)
  - Negative radiative forcing– 18.4 W/m^2 for 0.1 increase in Albedo
  - coupled global land surface model

Scope of the project

- To experimentally verify the increase in out going solar radiation at TOA
- Predict the outgoing solar radiation using a Radiative Transfer Model (RRTMG)

Methodology

Surface monitoring: 2 white roofs and 2 dark roofs

- **Pantnagar**; 29.03 ^{0}N, 79.49 ^{0}E, 235m above sea level
- Agricultural and Industrial area
- Aerosol and Gaseous emissions
  - residential cooking,
  - diesel vehicles

Heat flux sensor

During the process of Whitening

Four-component radiometers

Data monitoring on dark roof

Methodology

Surface monitoring: 2 white roofs and 2 dark roofs

- **Nainital**; 29.36 ^{0}N, 79.46 ^{0}E, ~ 1940 m above sea level
- Central Himalayan region
- Site has lower aerosol loading compared to Pantnagar but still significant AOD relative to background sites

Temperature sensor on Dark roof

Data monitoring on white roof

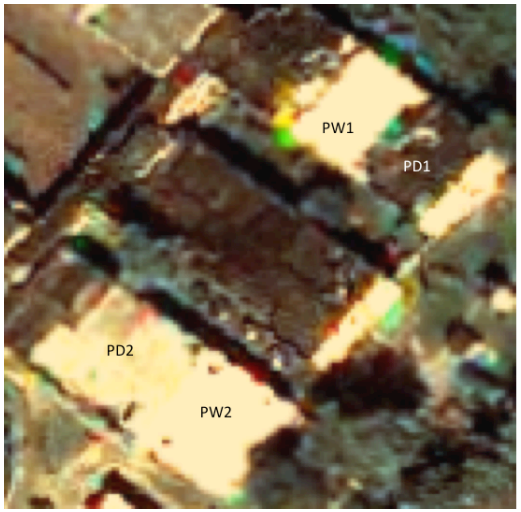
Data monitoring on dark roof

Methodology

Satellite Measurements of SW↑TOA Radiation: 6 shots

Pantnagar

- 21st October
- 26th December
- 20th March



True color image of light (PW1, PW2) and dark (PD1, PD2) roofs at the Pantnagar site taken the 21st OCT 2011

Naintal

- 13th October
- 21st December
- 20th March

True color image of light roofs (NW1, NW2) and dark roofs (ND1, ND2) at the Nainital site taken the 20th MARCH 2012.

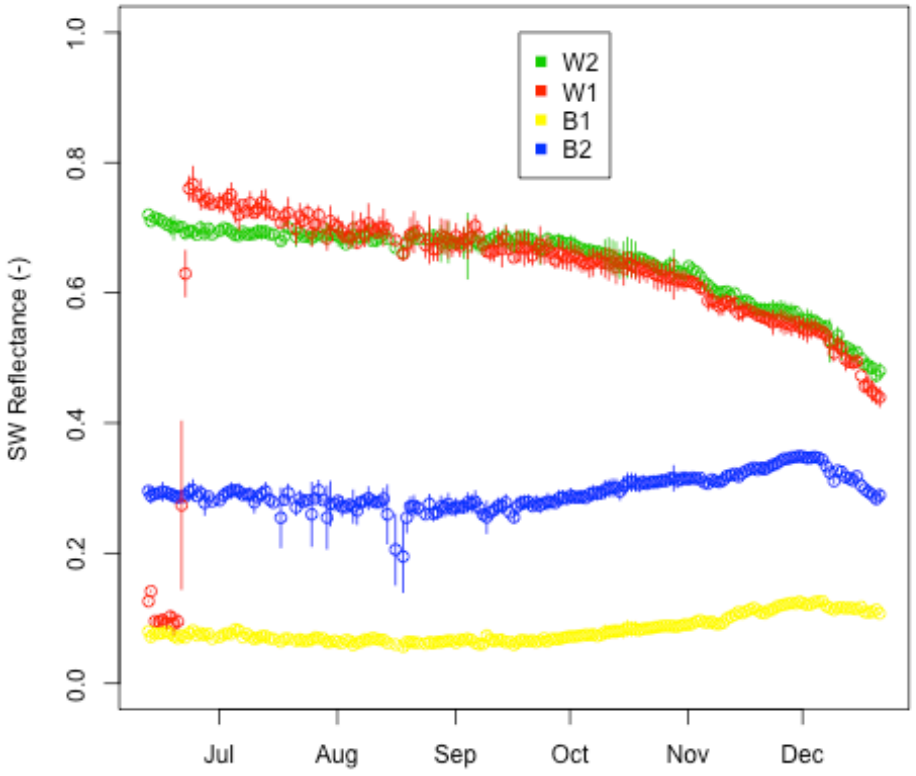
Soiling of Roof

- Roof reflectivity increased by paint application
- Continuous measurements capture temporal variations

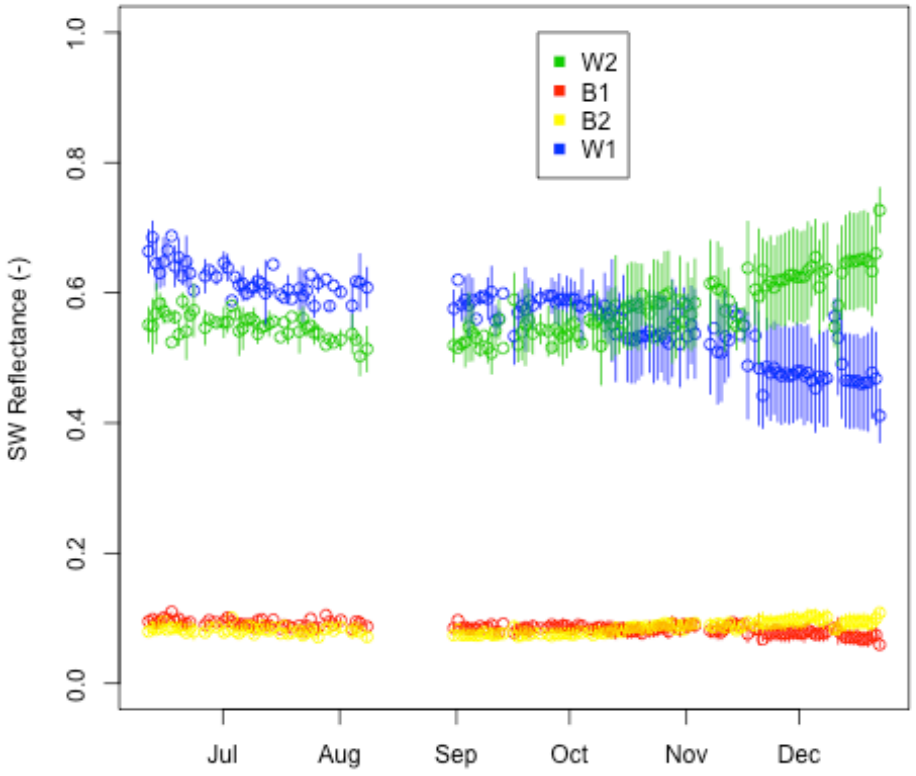
White roofs=W1, W2

Black roofs=B1, B2

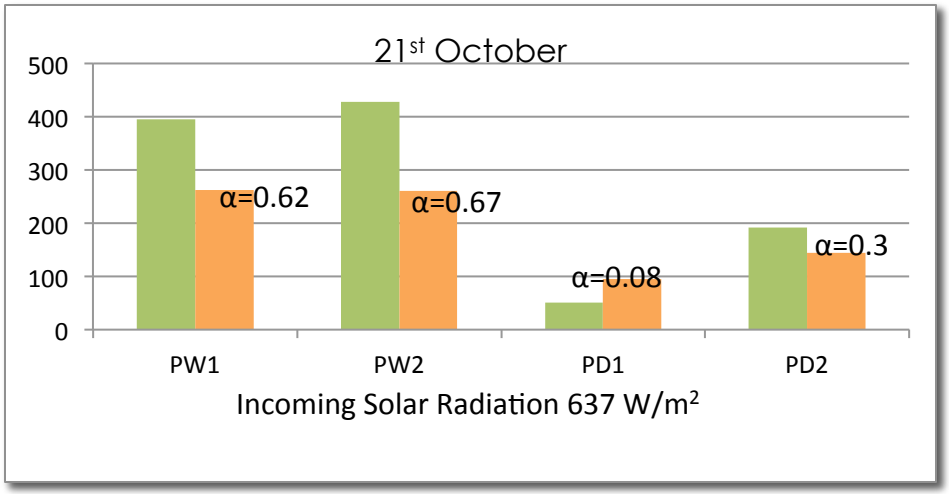
Pantnagar

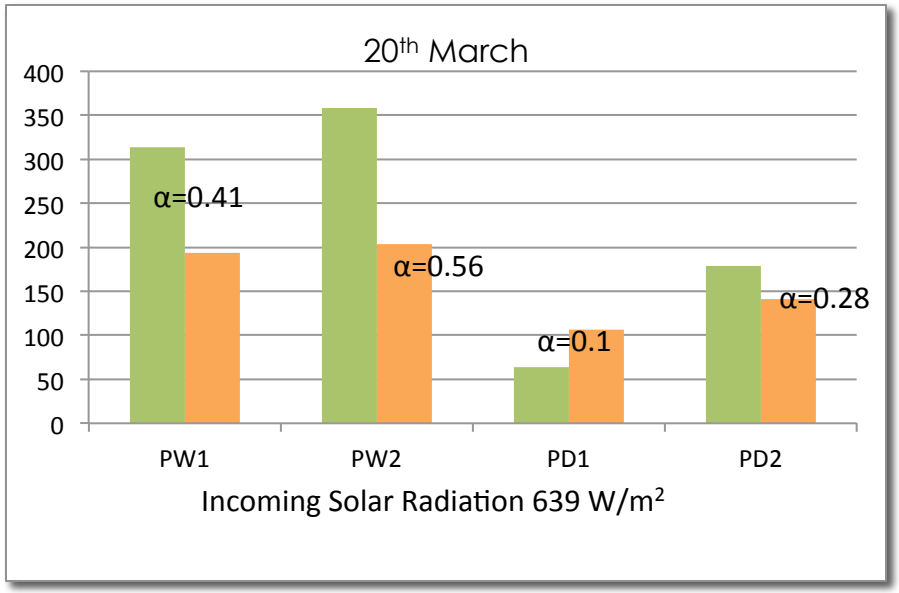


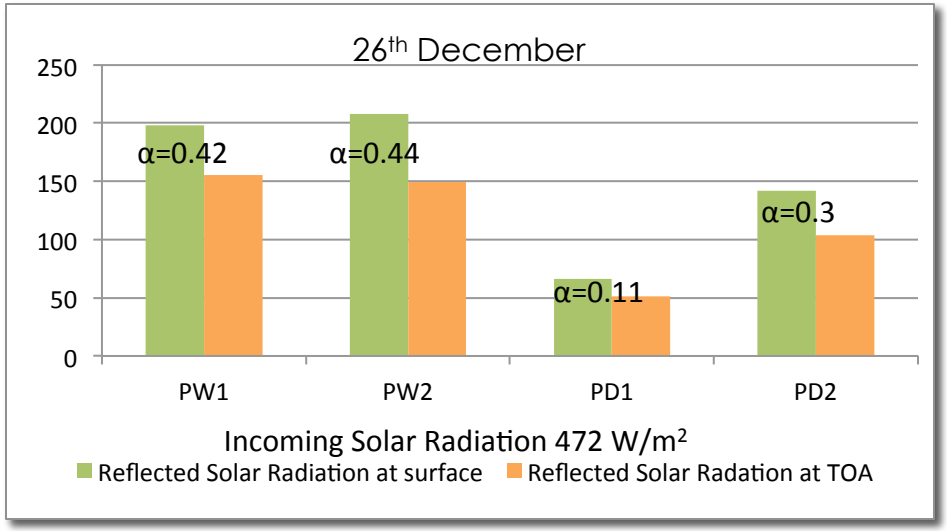
Nainital



Shortwave Outgoing Solar Radiation - Pantnagar



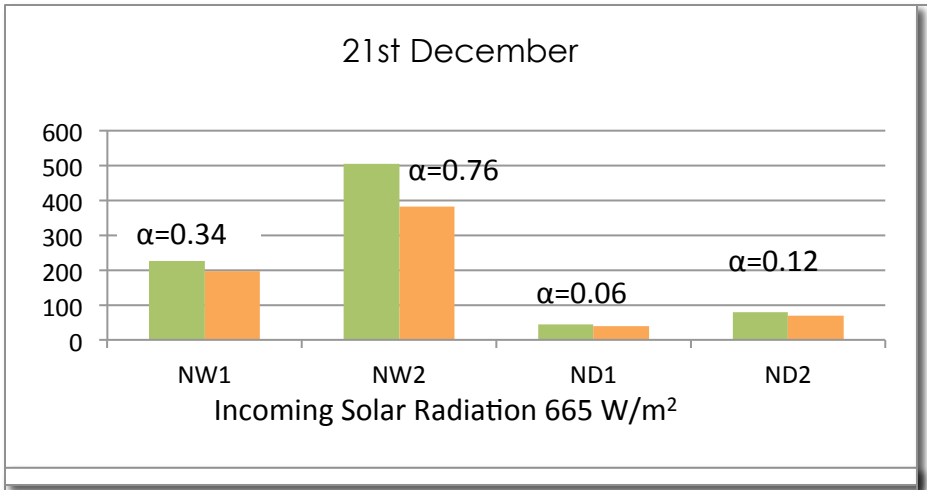


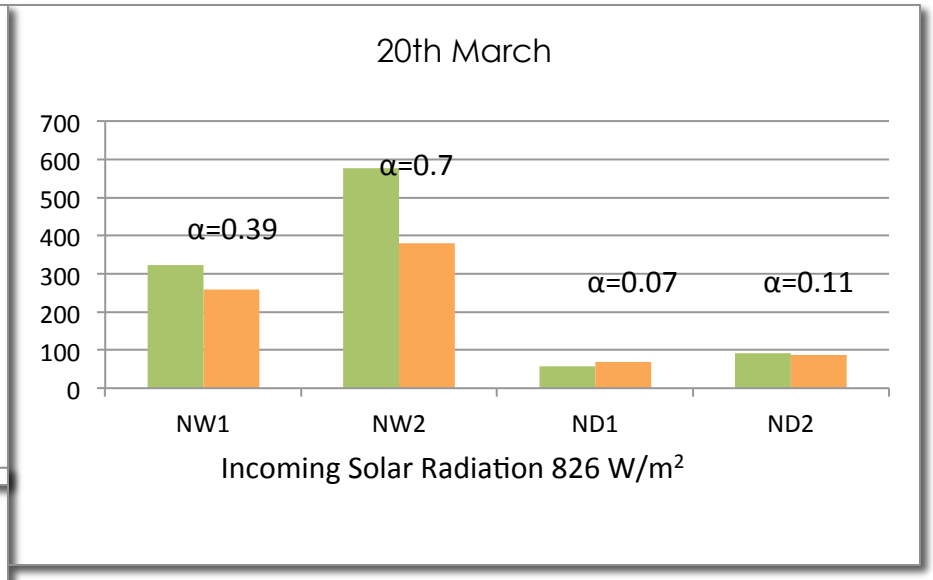


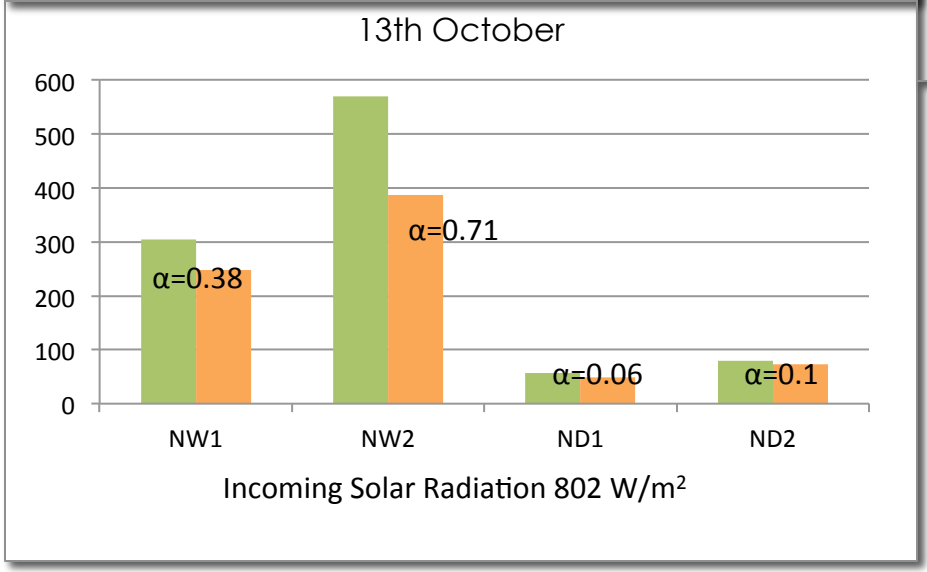
Reflected Solar Radiation at surface

Reflected Solar Radiation at TOA

Shortwave Outgoing Solar Radiation - Nainital







Reflected Solar Radiation at surface

Reflected Solar Radiation at TOA

Earth System Cooling with Reflective Roofs

IKONOS Quantifies Global Cooling Benefit

- GB Pant University, Oct, 2011

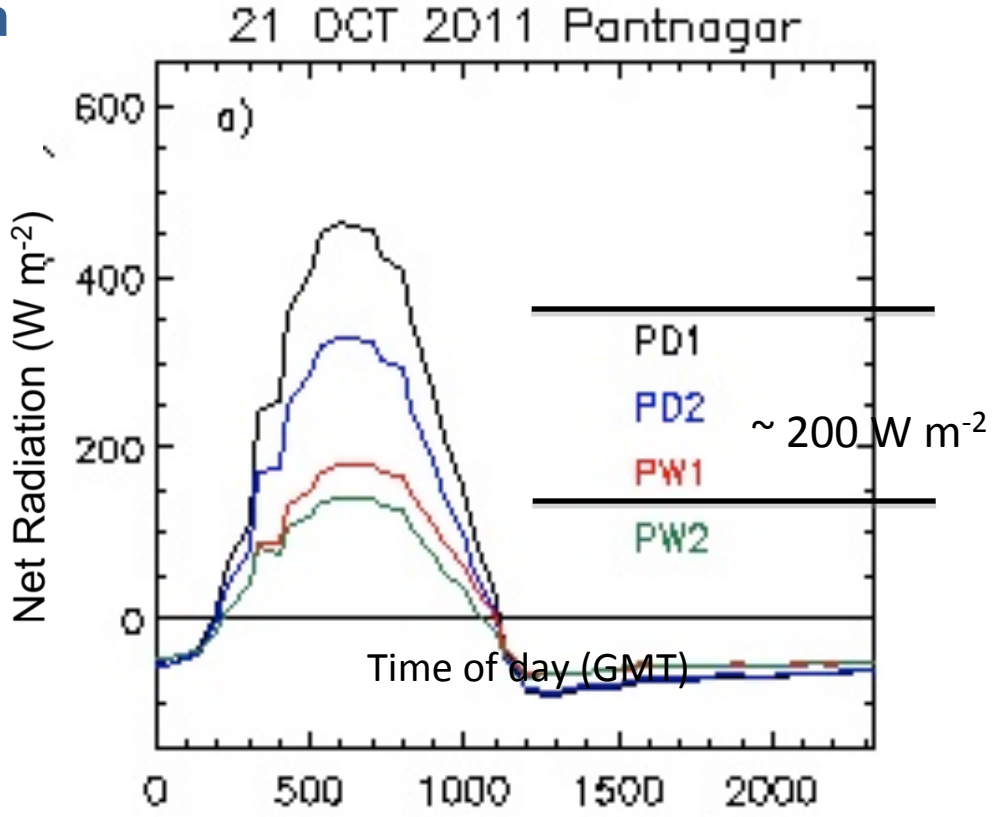
Roofs	Blue (W/m^2)	Green(W/m^2)	Red (W/m^2)	NIR (W/m^2)	Total (W/m^2)
W1	48	58	42	57	**205**
B1	23	23	13	19	**78**
W2	47	57	42	56	**202**
B2	29	33	22	31	**115**

- White roofs increase outgoing shortwave-NIR radiance at top of atmosphere by 80-120 W m^{-2}

Earth System Cooling with Reflective Roofs

White Roofs Reduce Net Radiation Loading and Heat Flux to Building

- White roofs reduce total (shortwave & thermal) net radiation loading by ~ 200 W m^{-2} in fall, 2011 (many times typical building heat loads)
- Only part of net radiation is returned to space, requiring space-borne measurements and model evaluation

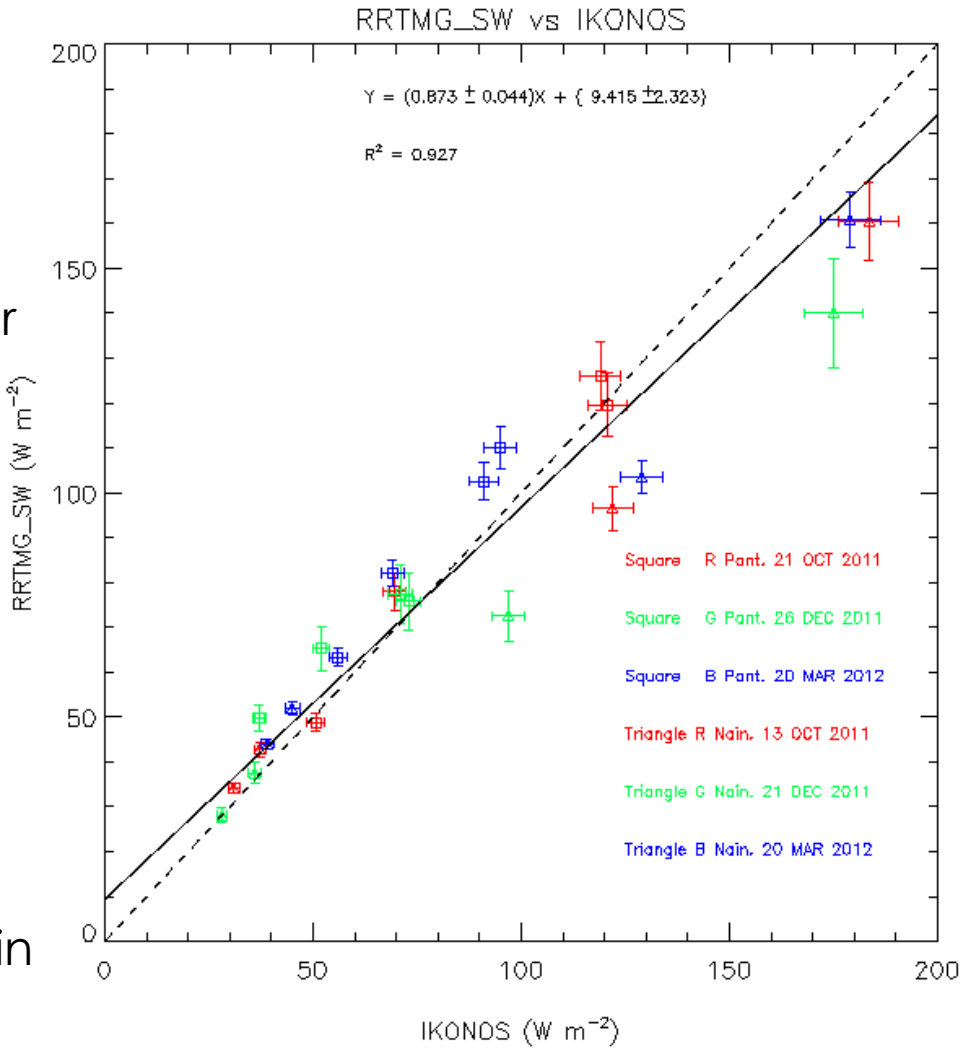


Earth System Cooling with Reflective Roofs

Successful Prediction of Global Cooling Benefit

Close agreement of measured (IKONOS) and modeled (RRTMG) top-of-atmosphere SW radiance for both sites and three seasons demonstrates method can be applied to urban scales

(Salamanca et al., accepted and in press)



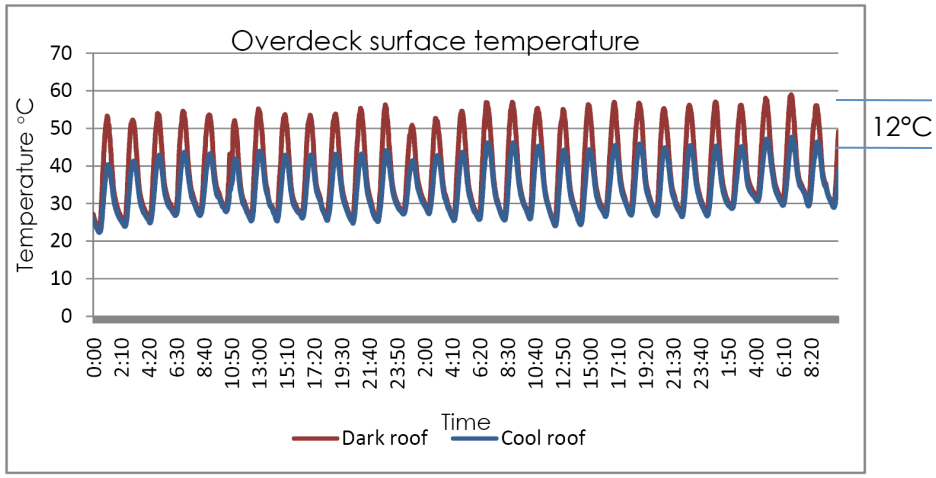
Pantnagar Site (Concrete Roof)

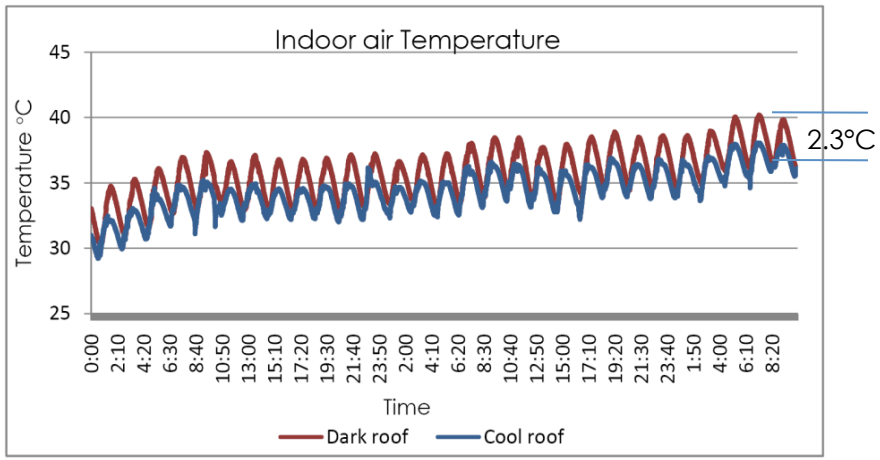
Warm and Humid (29°C – 4°C)
29.01°N, 79.29°E

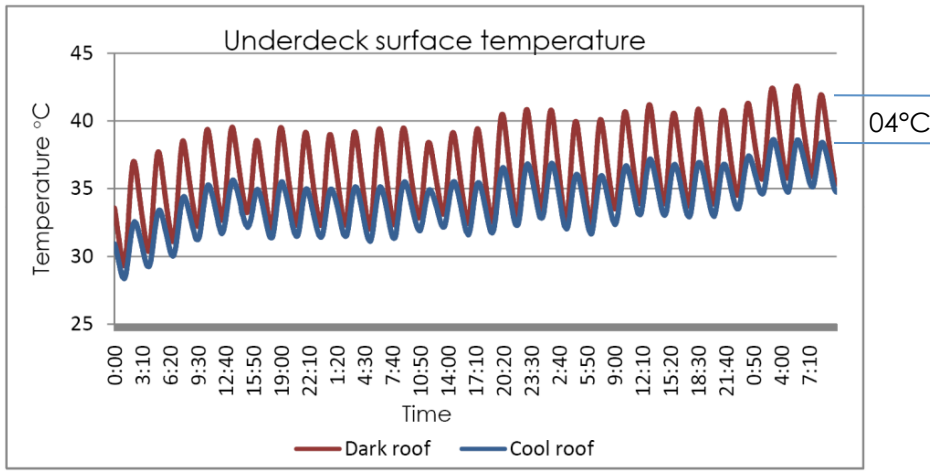
Center for Basic Sciences and Humanities, Pantnagar University, Uttarakhand

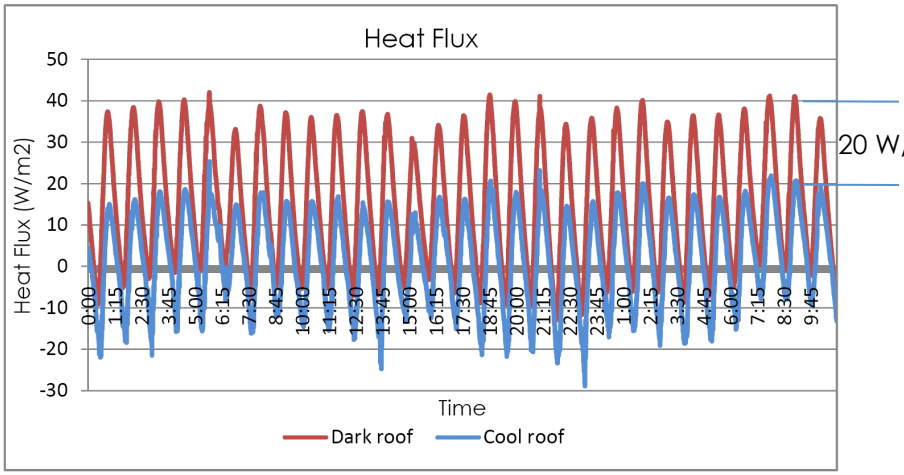
Block A – Biophysics center wing Block B – Environmental science wing
W1 & W2: White roofs,B1 & B2: Existing roofs

Temperature and Heat Flux (6-31 May 2012)

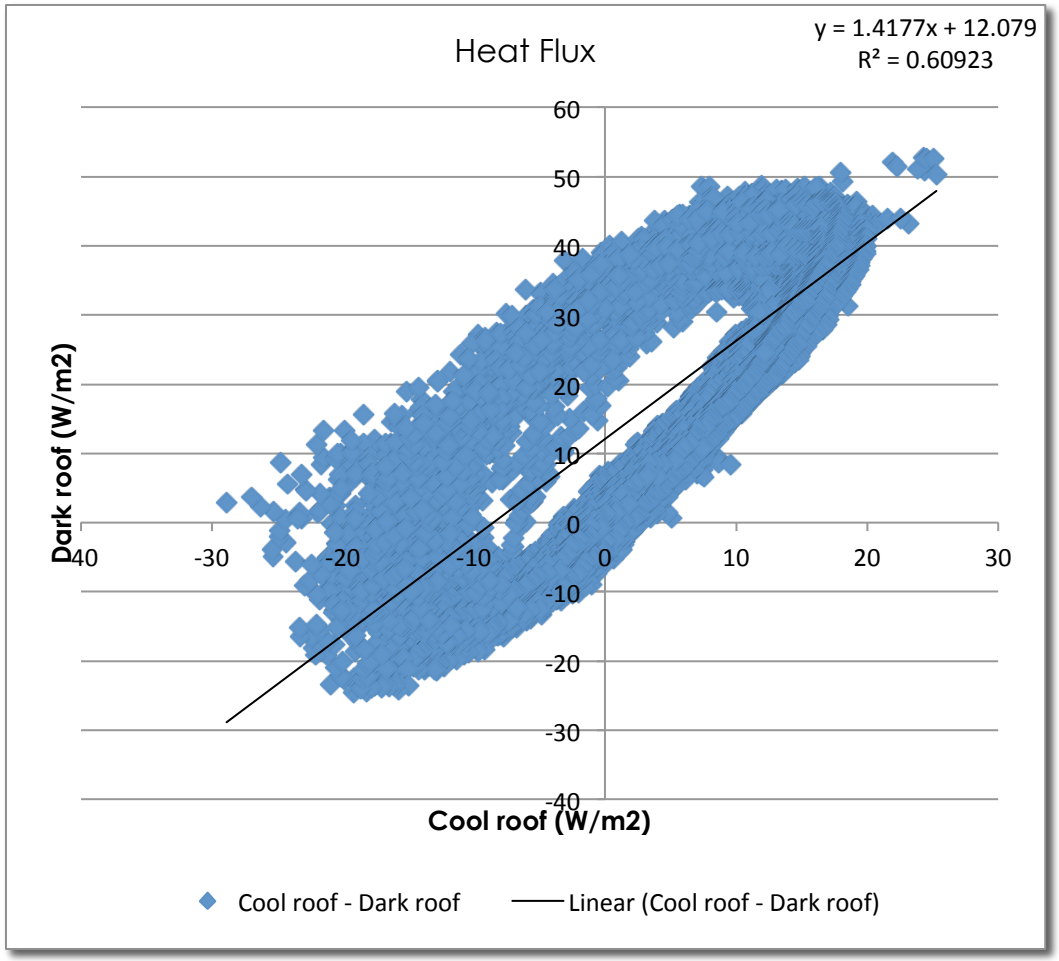




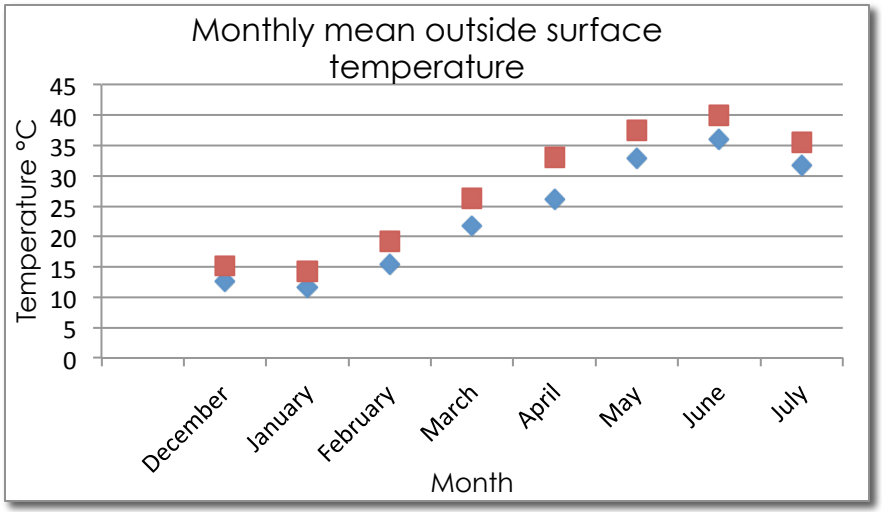


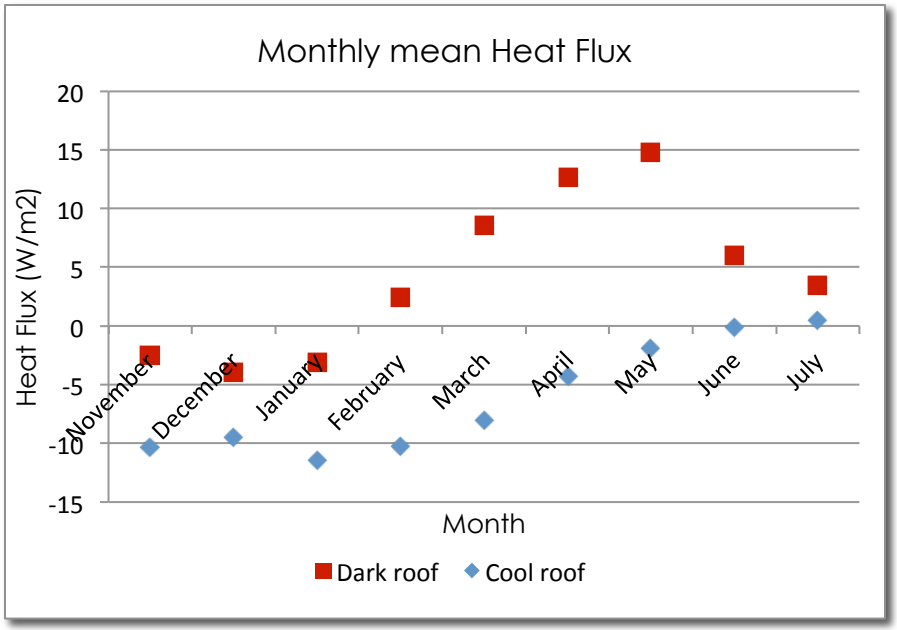


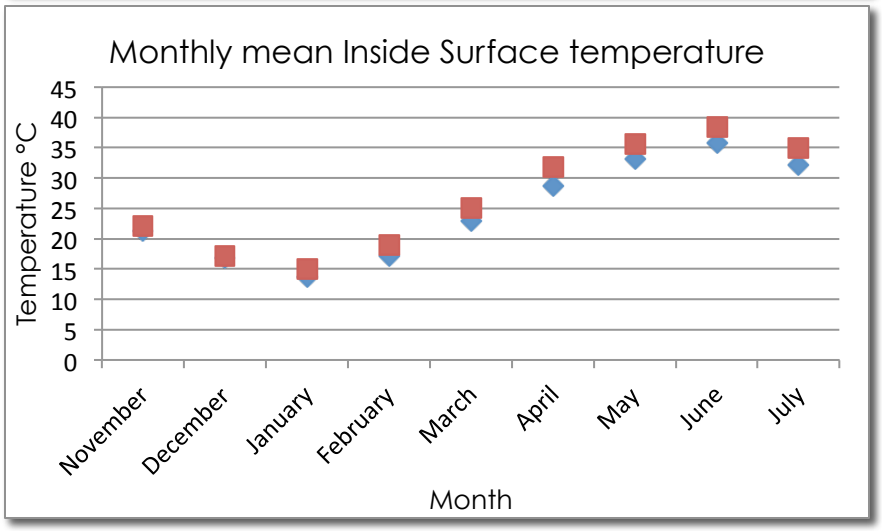
Heat Flux (May 2012)



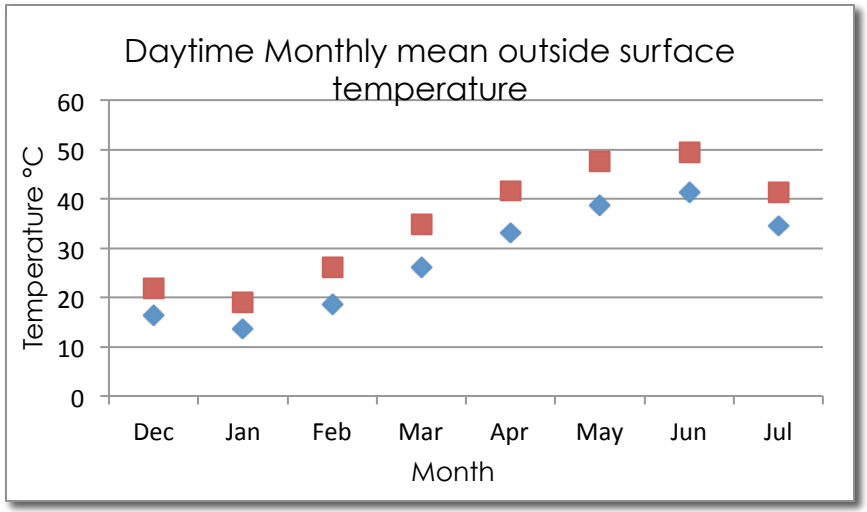
Monthly mean Temperature and Heat Flux

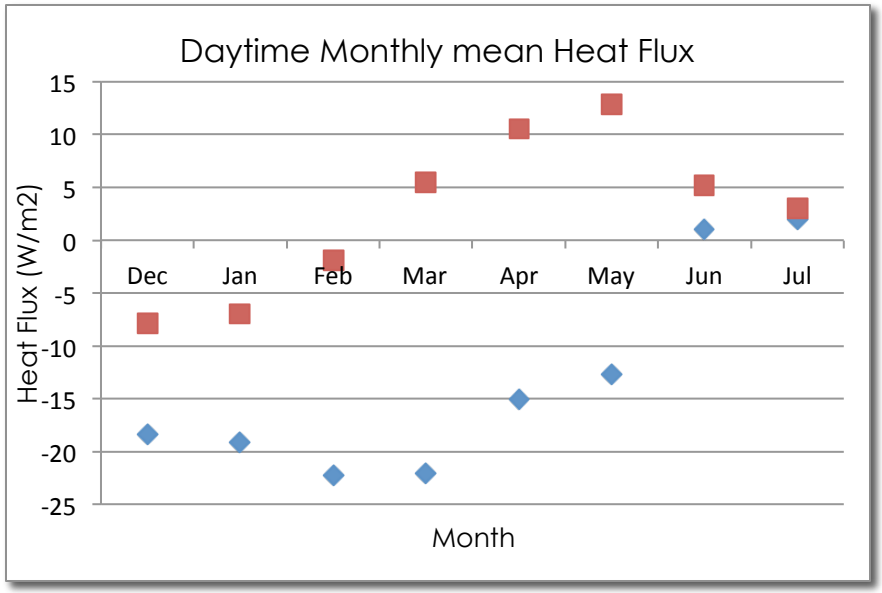


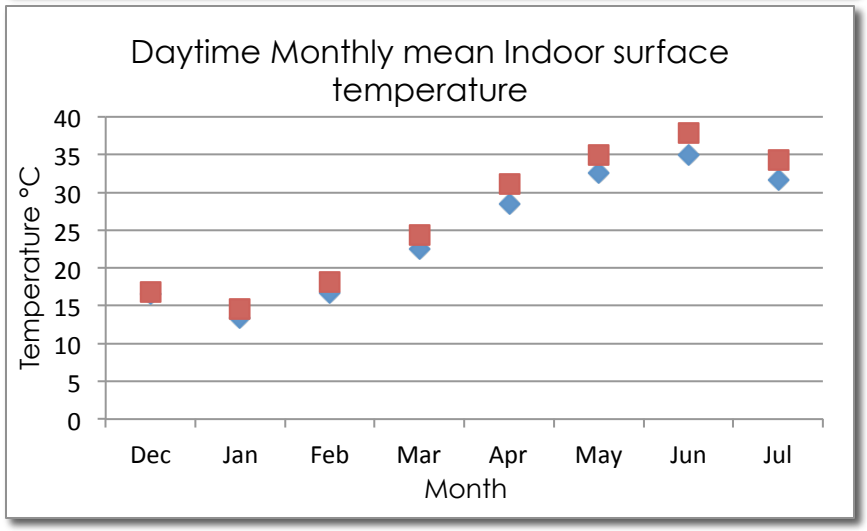




Daytime monthly mean Temperature and Heat Flux

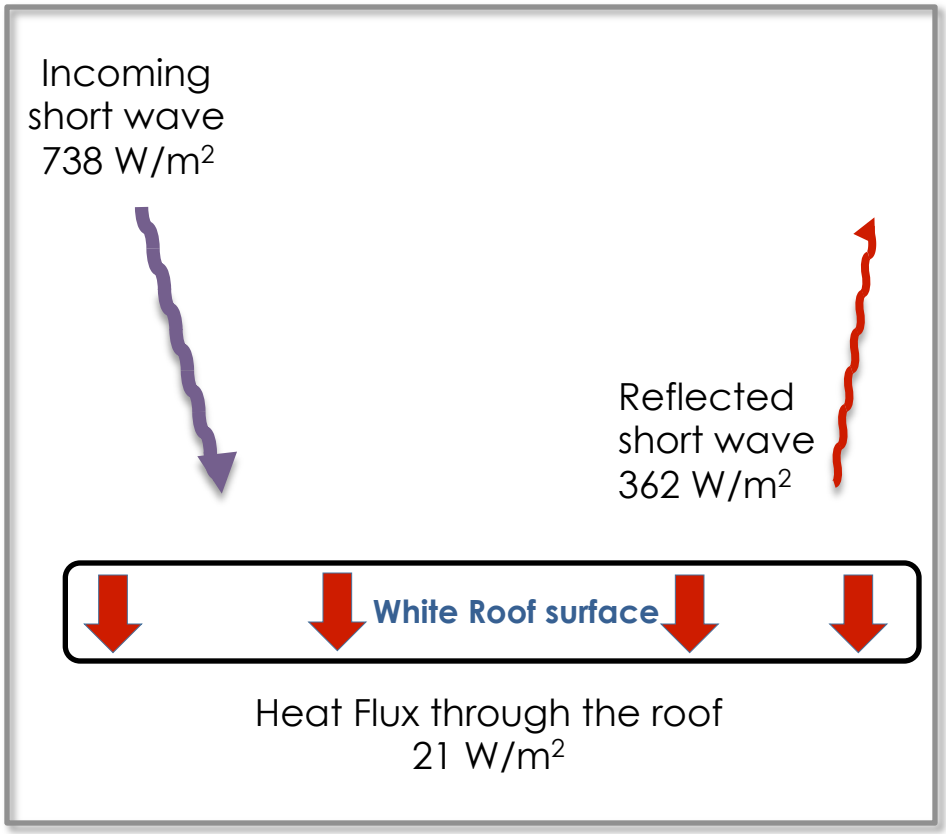


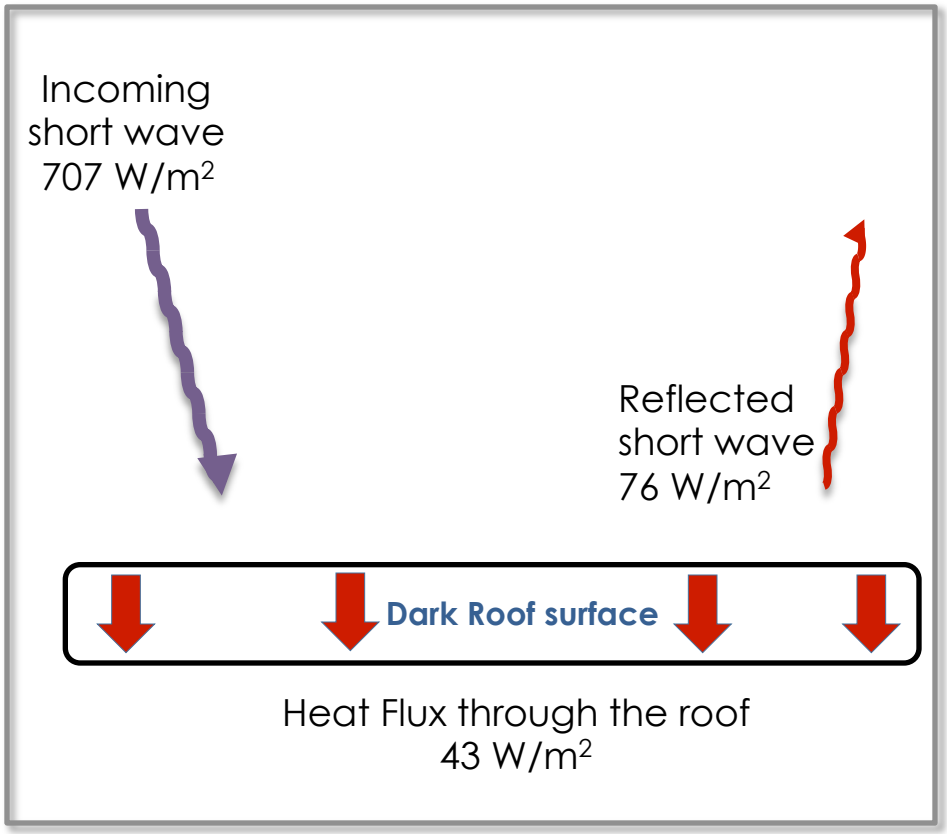




Day time – 8:00 to 18:00

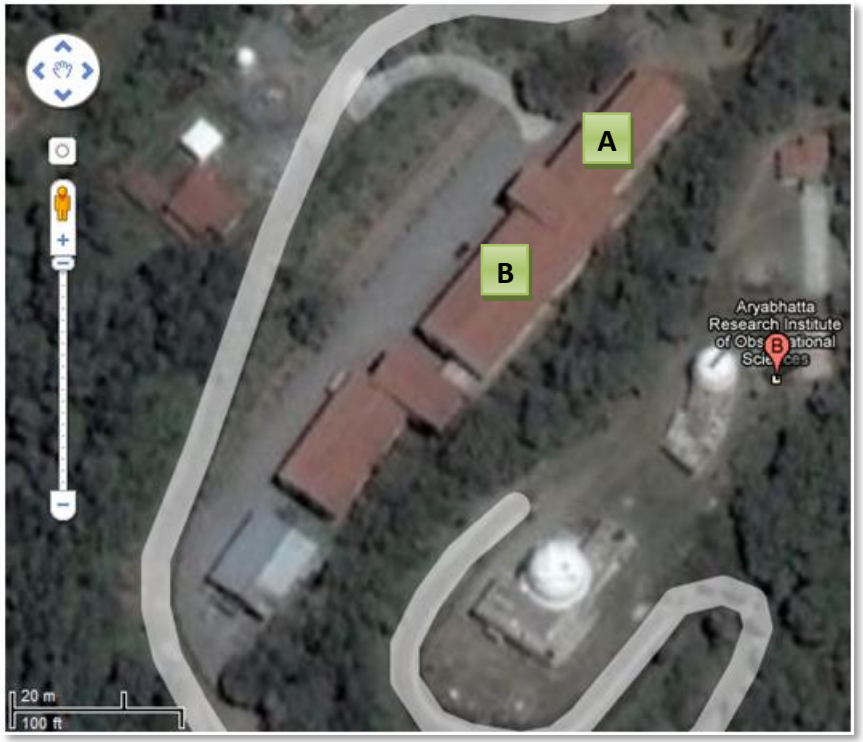
Energy balance of roof (4th March, 2012, Pantnagar)





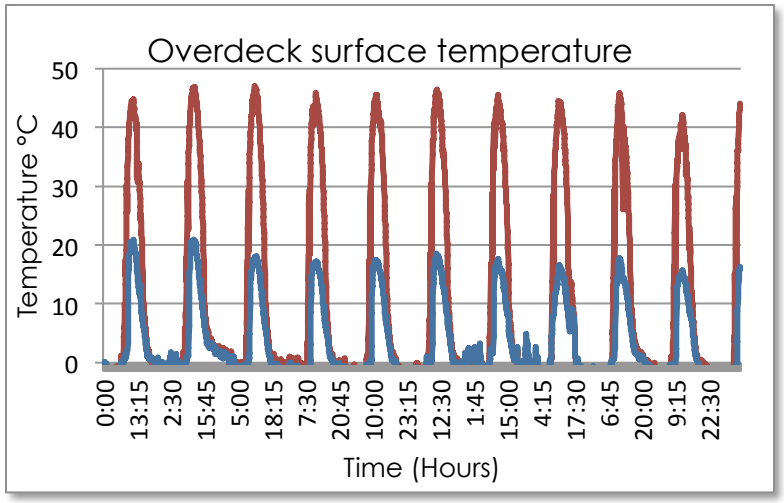
Nainital site (Metal Roof)

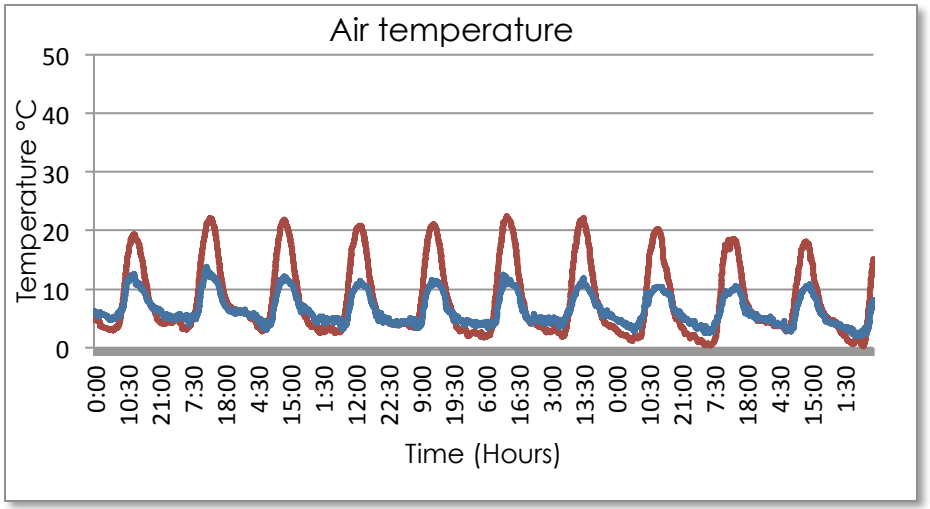
Cold Climate (Summer: 27°C – 10°C, Winter: 15°C – 0°C)
29.22°N, 79.27°E

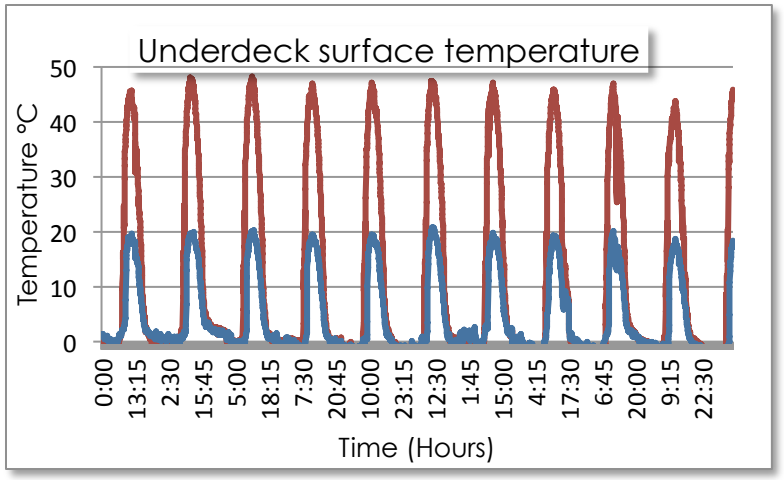


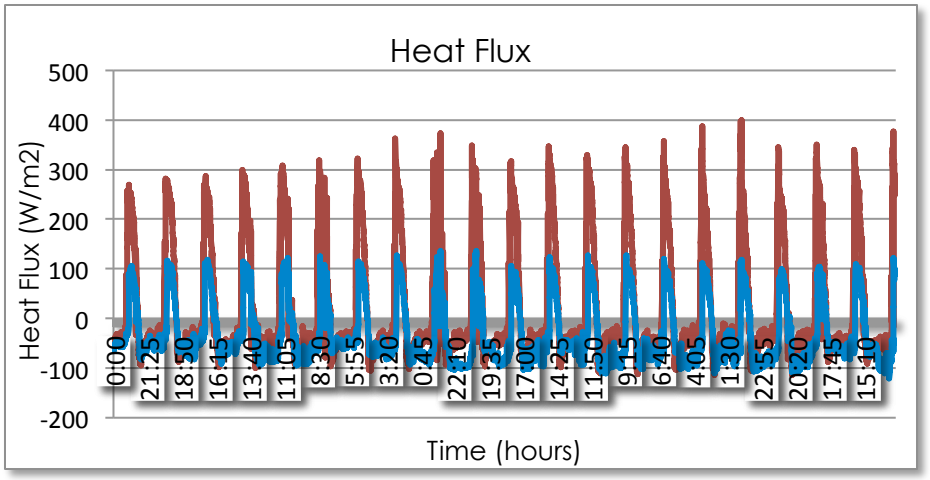
Aryabhatta Research Institute of Observational Sciences

Temperature and Heat Flux (1-21 Dec 2011)

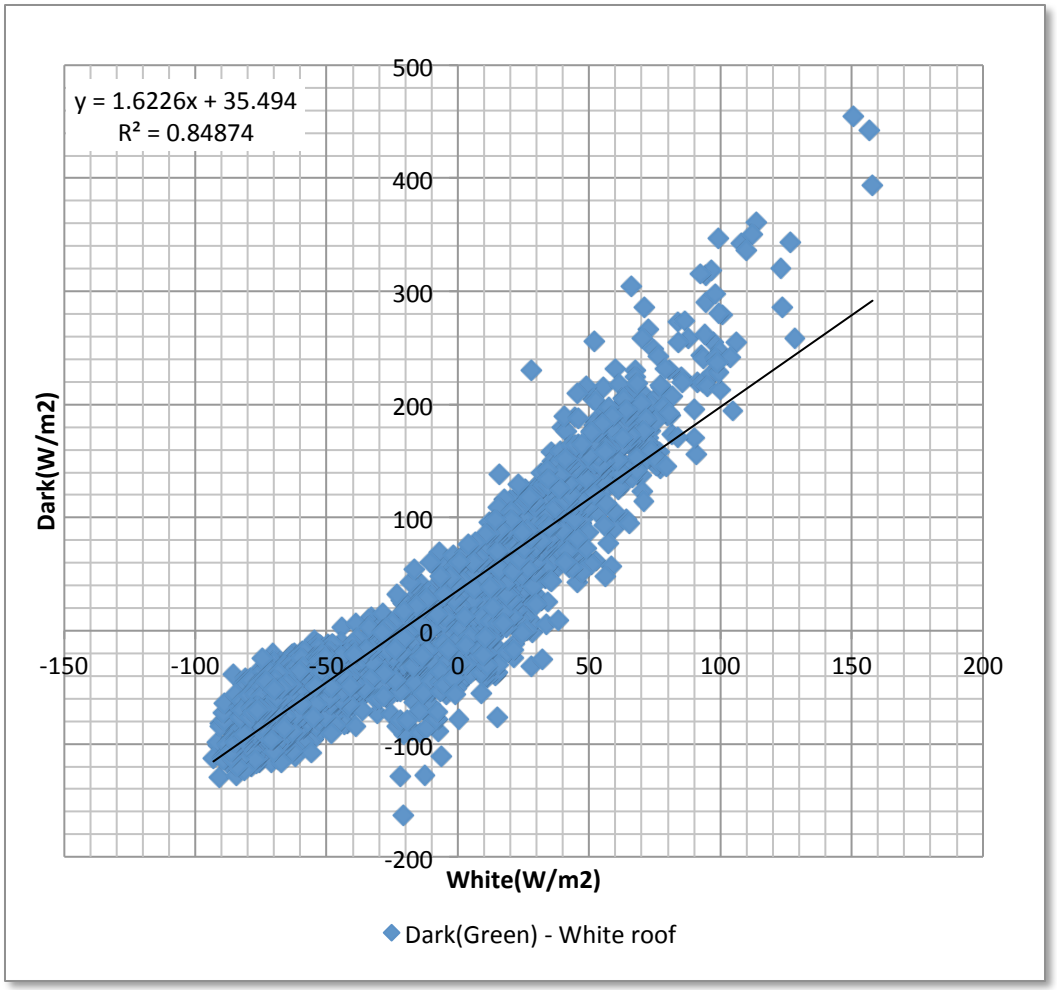




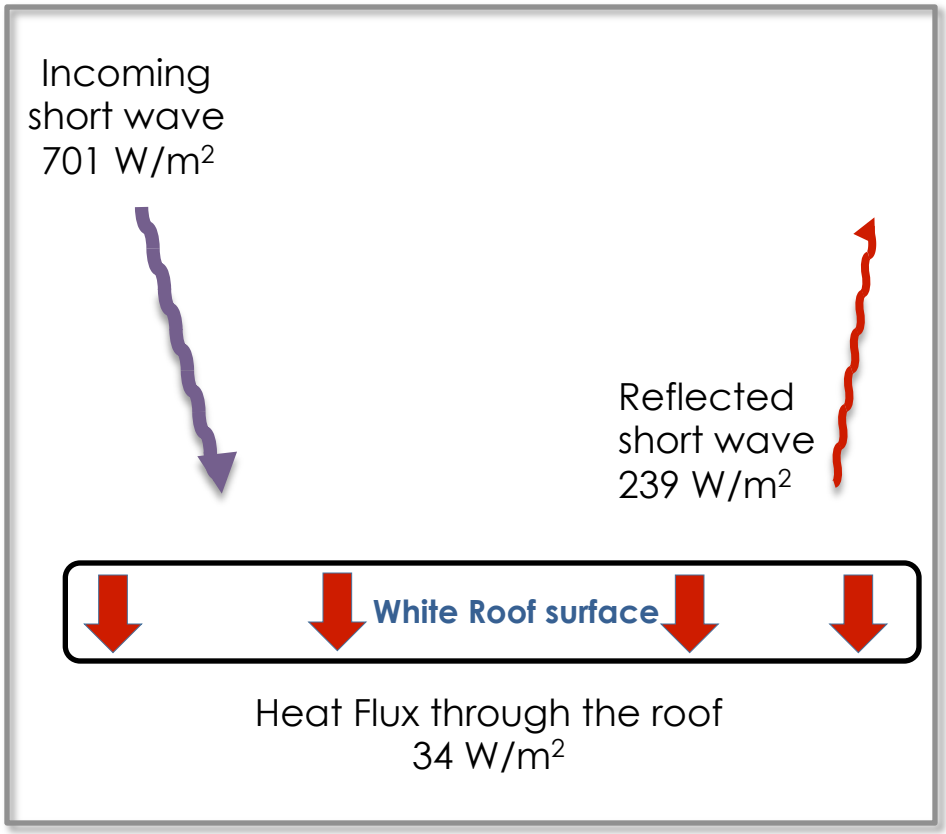


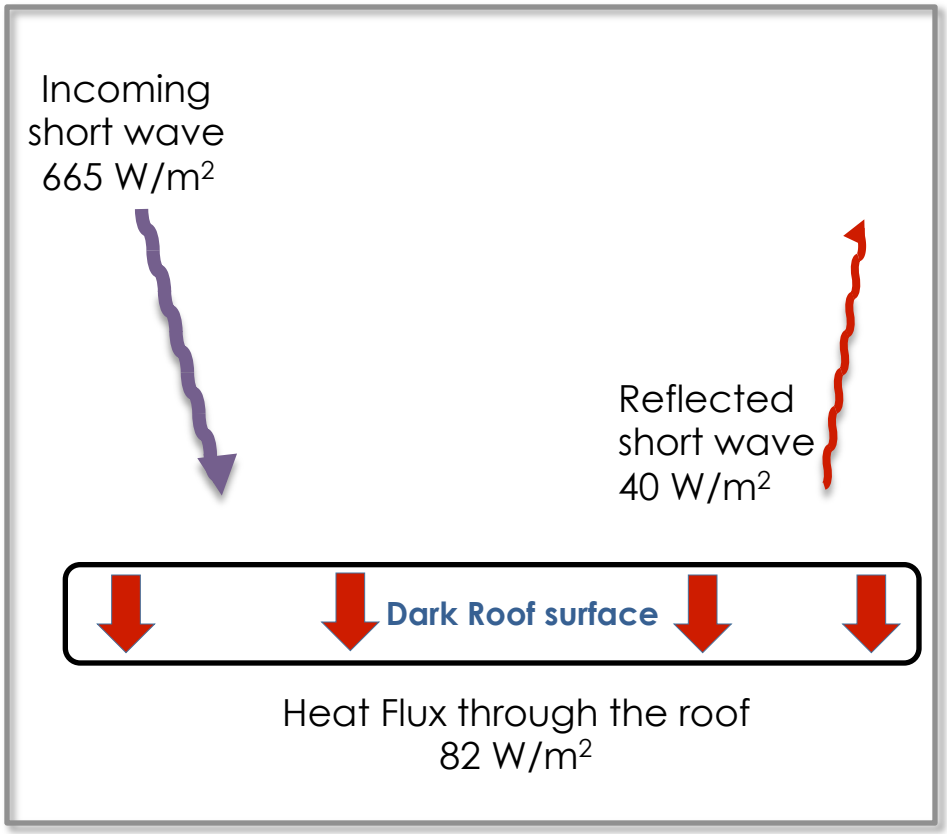


Heat Flux - Dark-Cool roof (1-21 Dec 2011)



Energy balance of roof (21st December, 2012,Nainital)





Results* for Pantnagar

- Daily mean benefit for albedo increase of 0.1 is ~ 20 Wm^{-2} for Pantnagar (~ 40 Wm^{-2} for Nainital)
- Heat flux reduction of ~ 20 Wm^{-2} is observed in the month of May
- Over deck Temperature reduction of 12^{o}C
- Under deck Temperature reduction of 4^{o}C
- Indoor temperature reduction of 2-3^{o}C

* These are the preliminary results, further analysis is being carried out for final results

Thank You

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