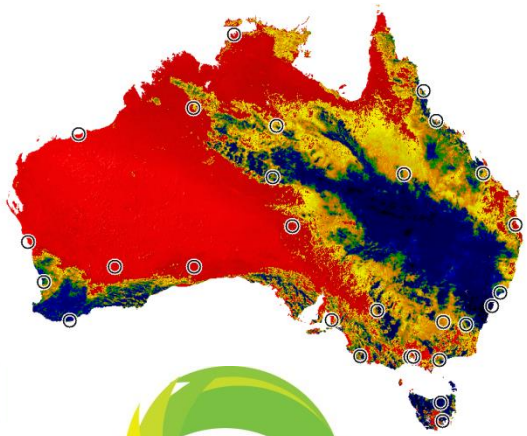
Comparison of Satellite Estimated Hourly Solar Data with Coincident Ground Based Measurements

and their Applications in Industry and Commerce



exemplary ENERGY PARTNERS

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Introduction

Satellite estimated hourly solar data assumes that:

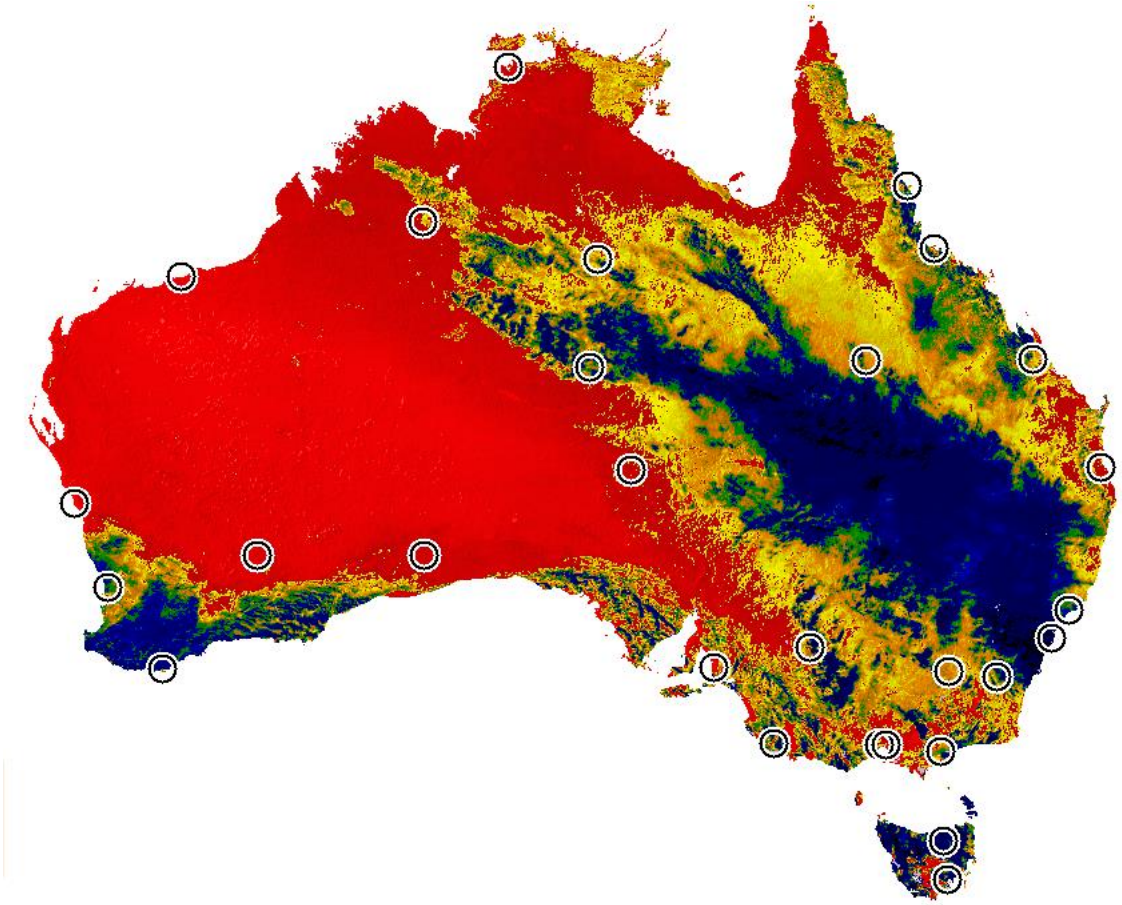
- A cloud is above the piece of ground that the satellite “sees” when the cloud is not there; and
- The cloud’s shadow falls on that same piece of ground.

This is a computationally convenient simplification.

Does it matter that it is obviously imprecise?

We look at the theory and its implications when the data is applied in industry and commerce.

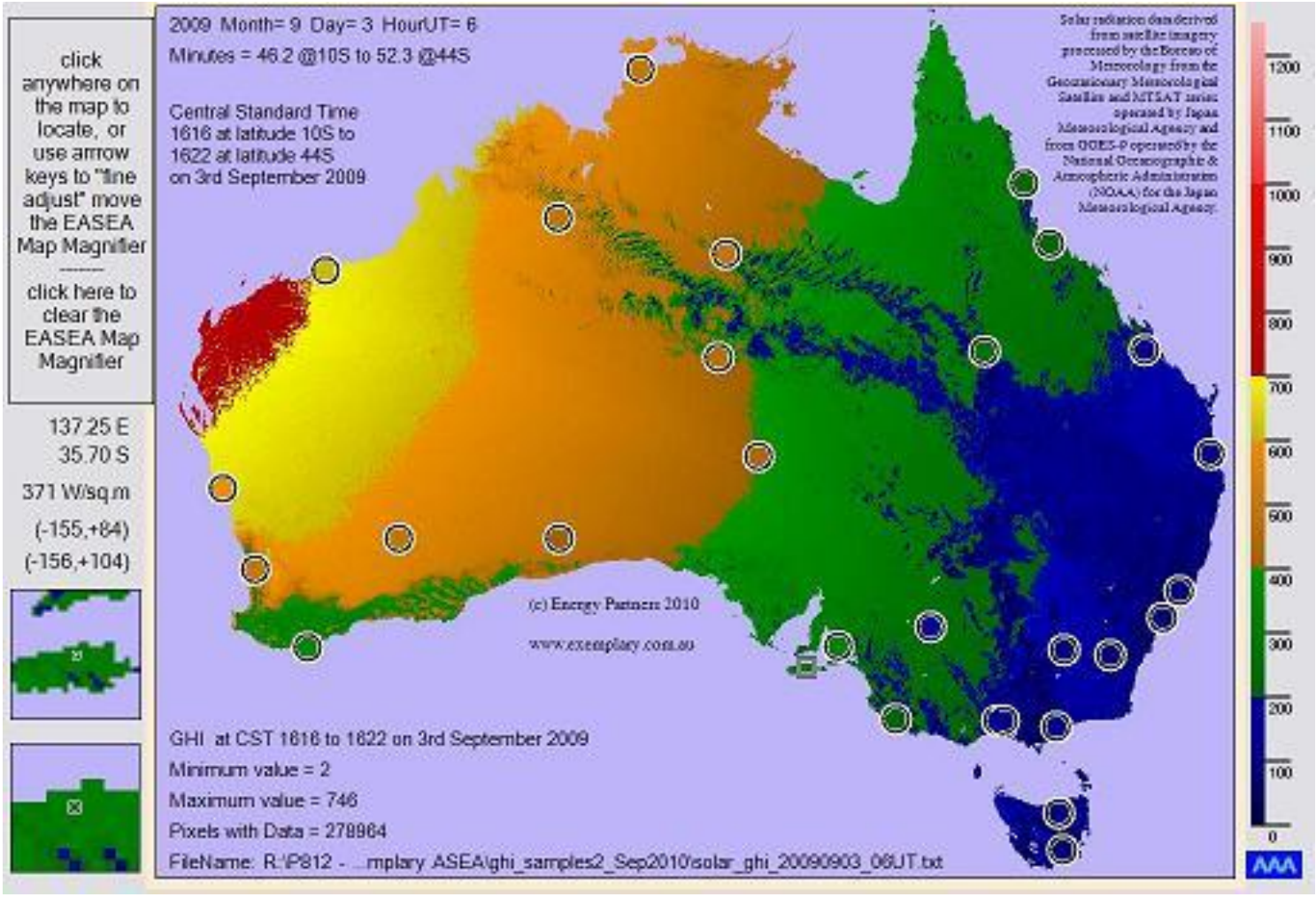
Weather Data - satellite estimation



single scan image with 28 sites of the
Australian Solar Radiation Data Handbook overlaid

Weather Data - satellite estimation

Exemplary Australian Solar Energy Atlas



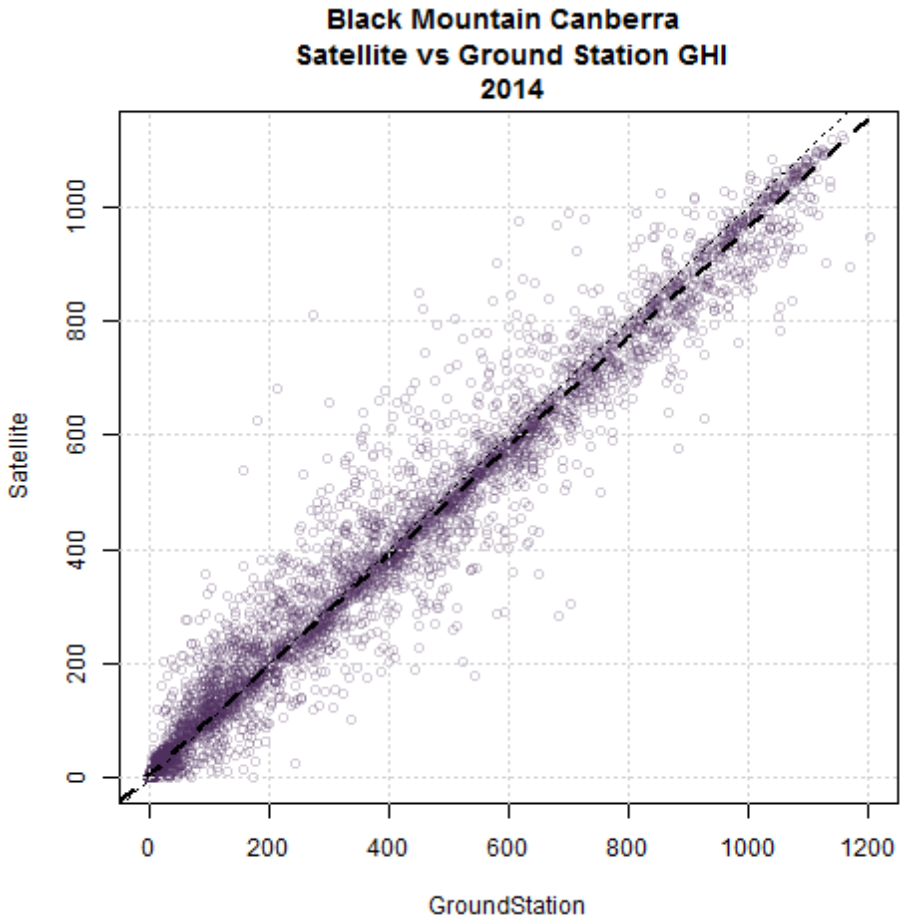
Exemplary Weather and Energy Index - Canberra

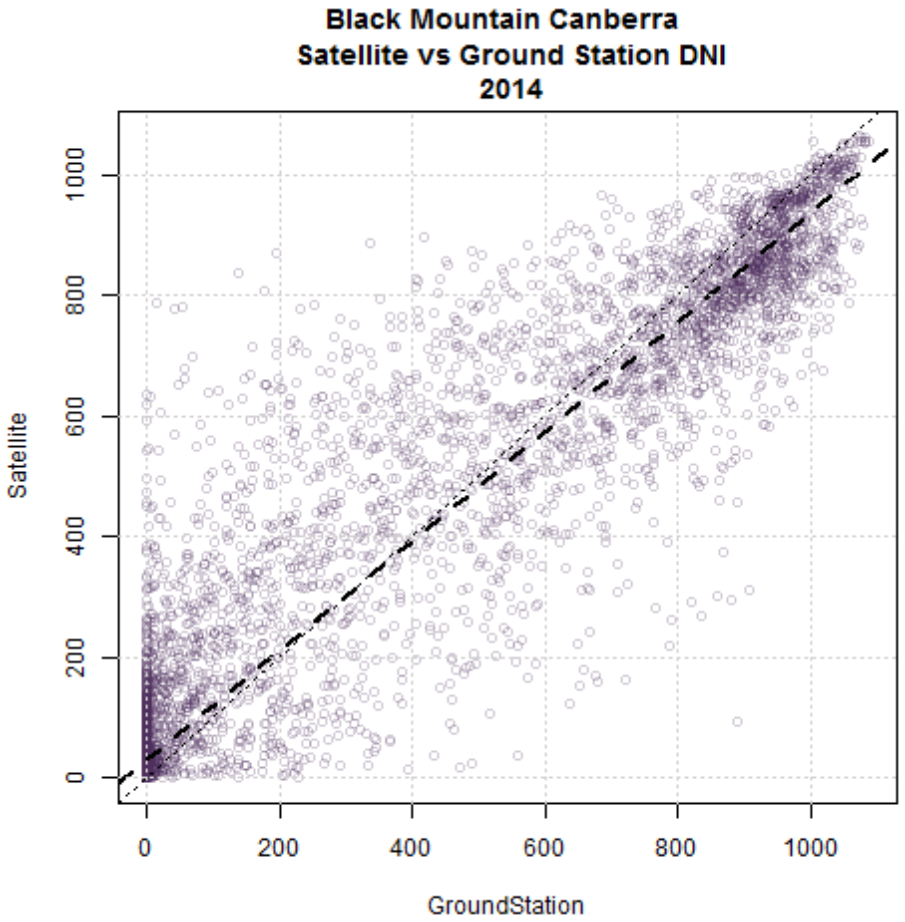
CSIRO Black Mountain Automatic Weather Station installed for the monitoring of solar PV installation test

Exemplary Weather and Energy Index - Canberra

CSIRO Black Mountain Automatic Weather Station
solar irradiation and cloud measurement equipment

Solar Irradiation Comparison

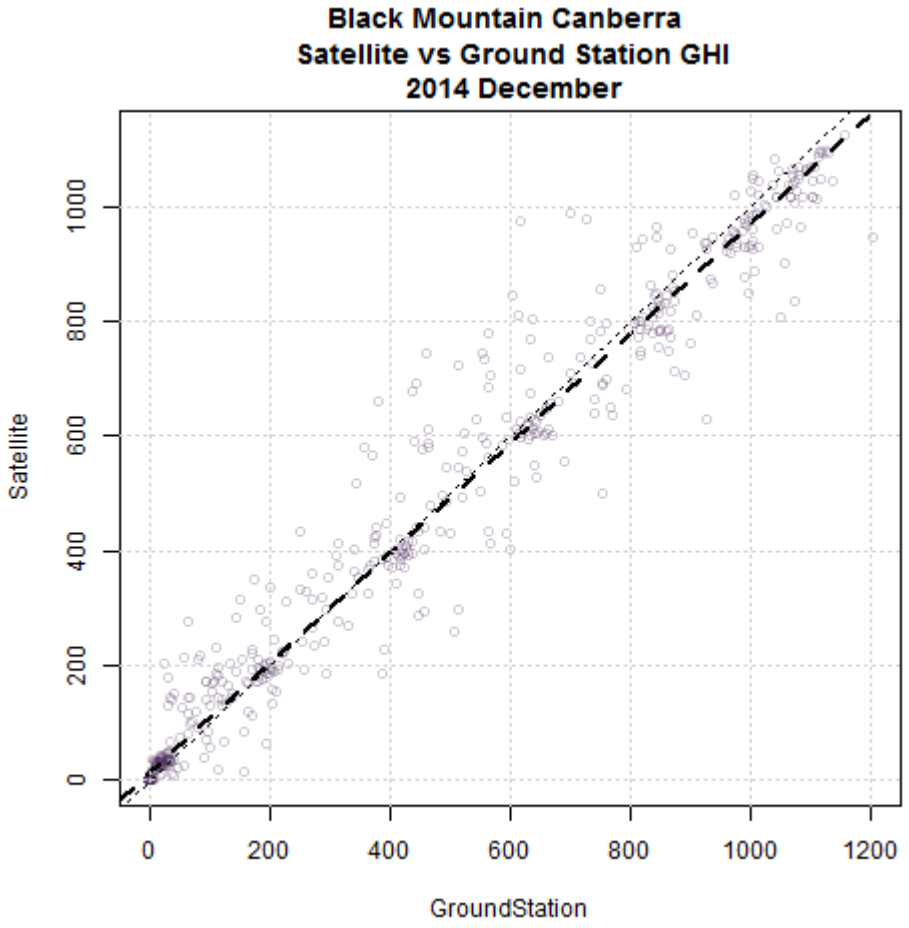


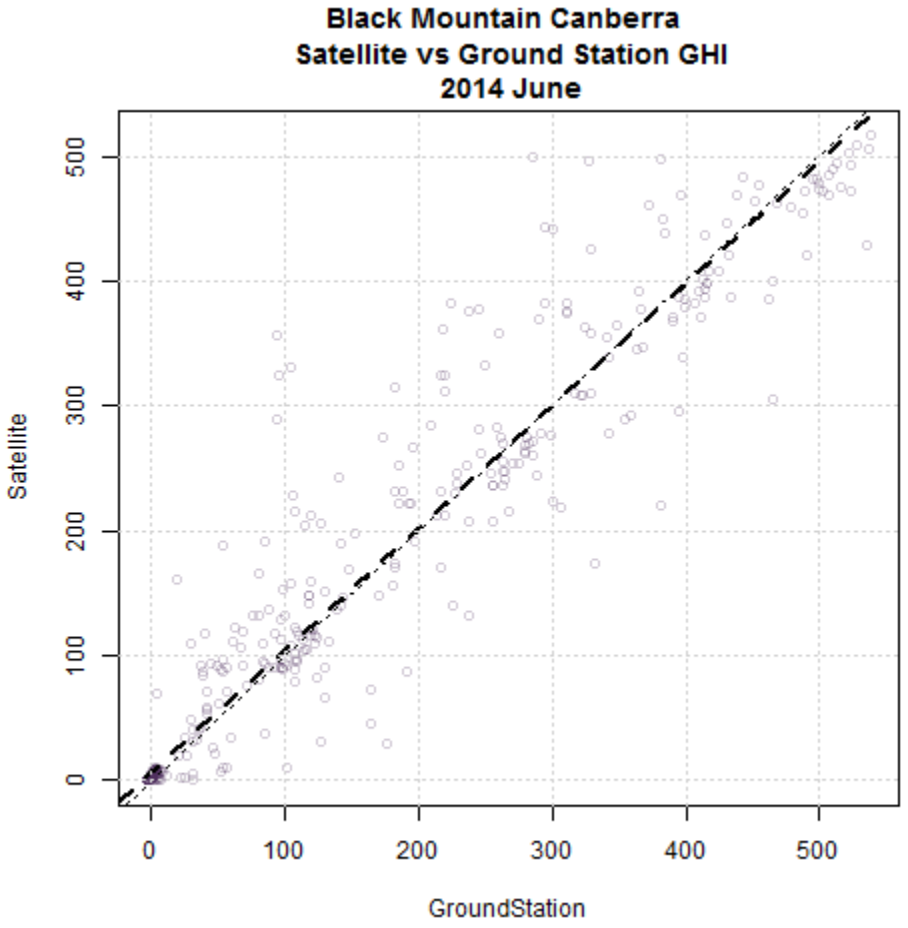


2014 Whole Year – Global (GHI)
Line of best fit: y = 0.95x + 9.57
R^2 value: 0.97

2014 Whole Year – Direct (DNI)
Line of best fit: y = 0.91x + 31.48
R^2 value: 0.91

Seasonal GHI Comparison





December 2014

Line of best fit: y = 0.96x + 15.49

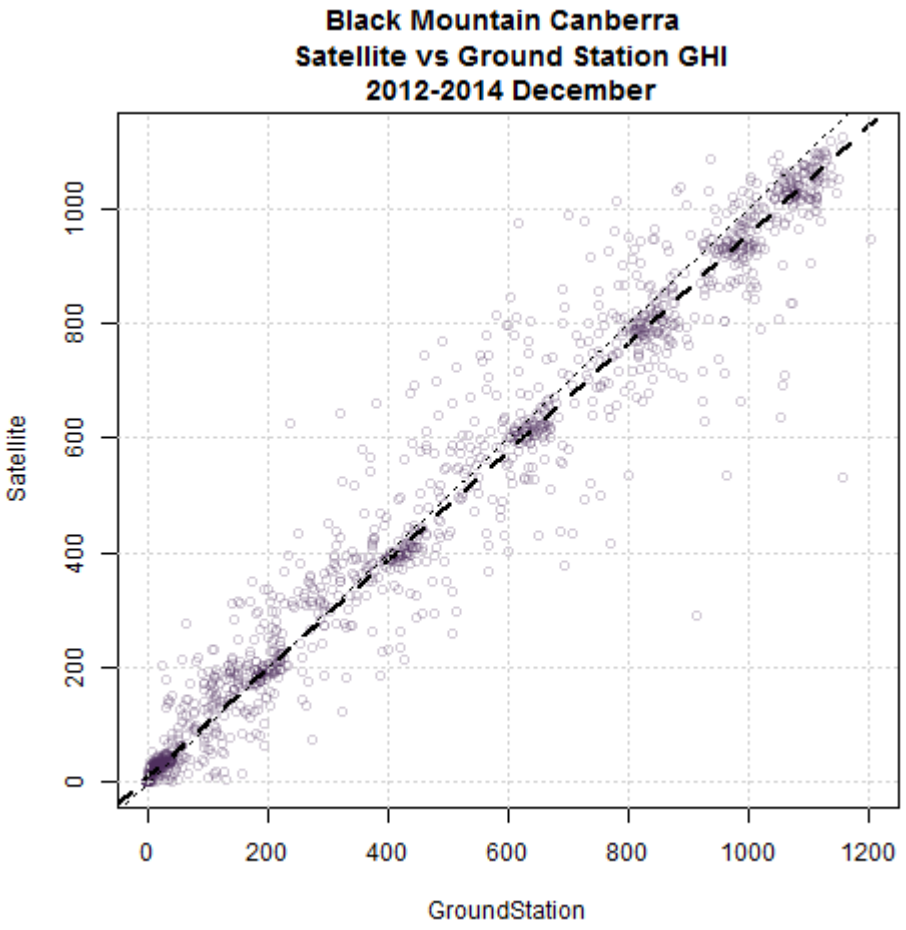
R^2 value: 0.97

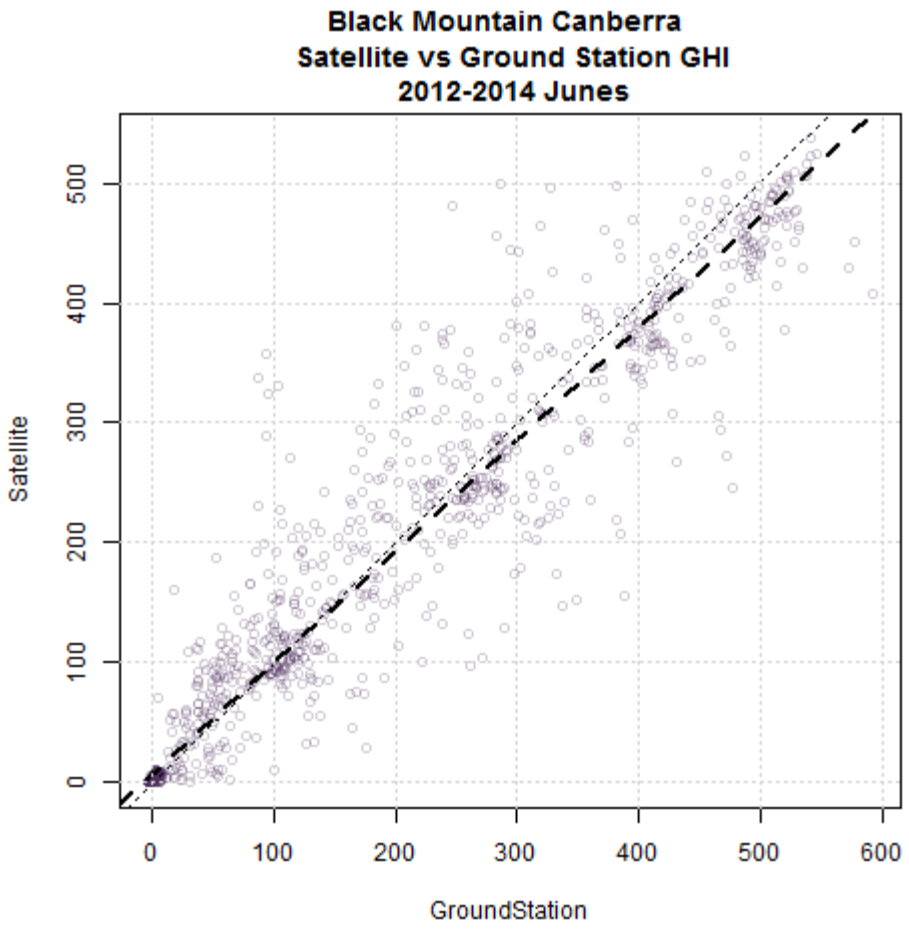
June 2014

Line of best fit: y = 0.98x + 7.6

R^2 value: 0.93

Seasonal GHI Comparison

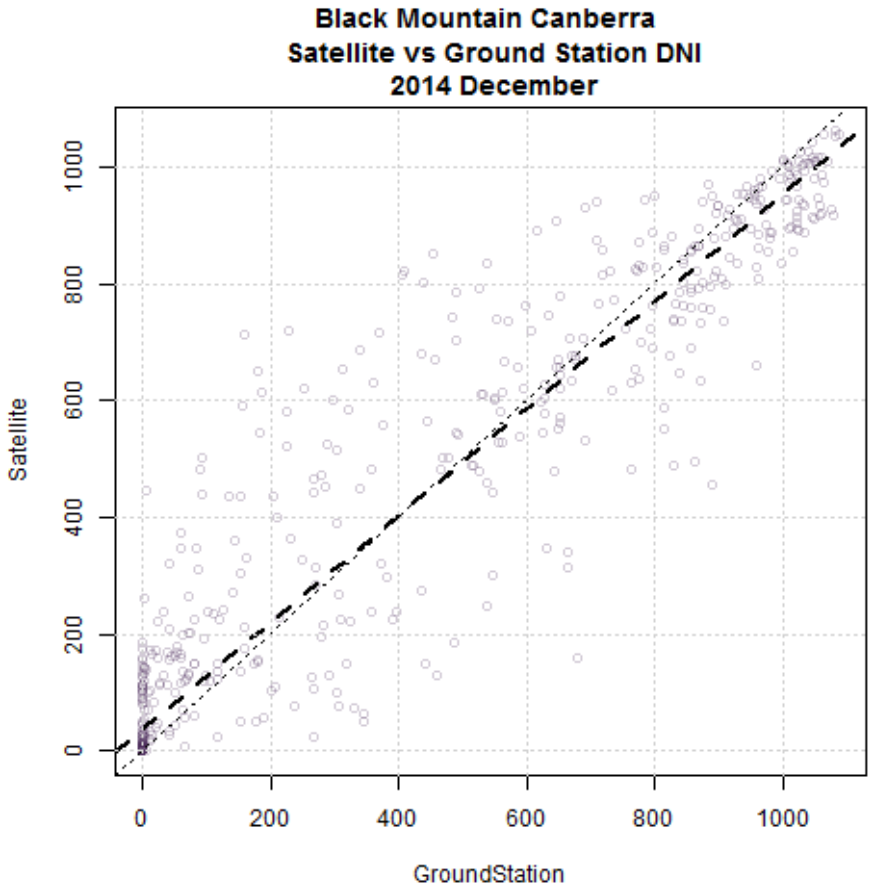


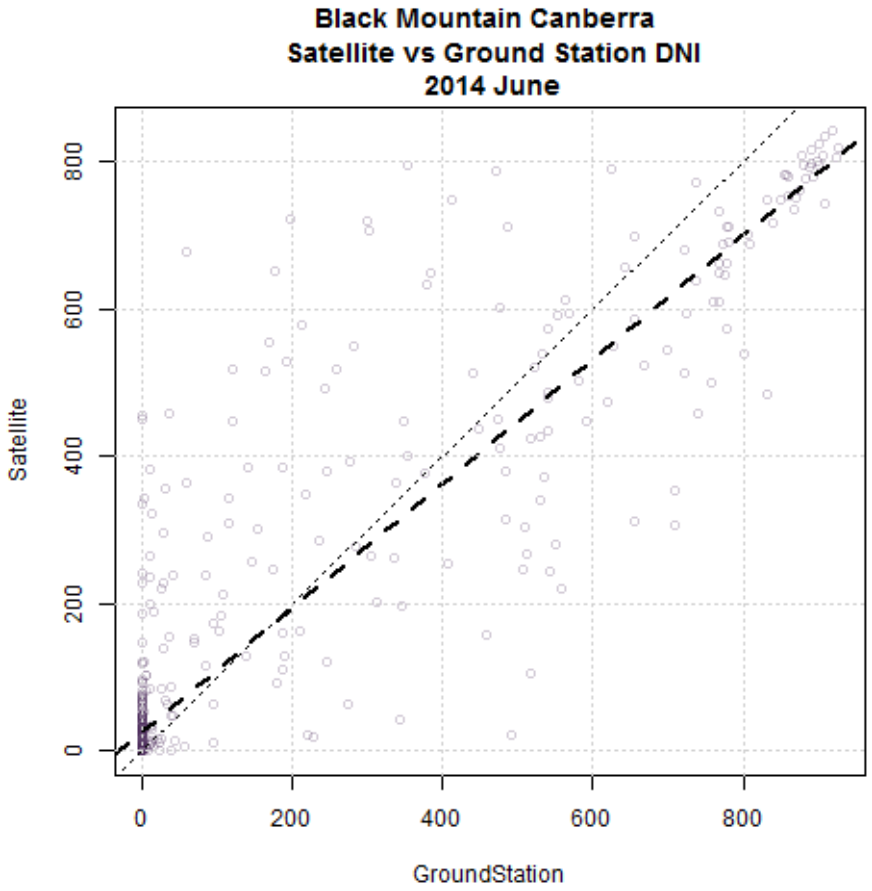


Decembers of 2012 to 2014
Line of best fit: y = 0.94x + 13.13
R^2 value: 0.97

Junes of 2012 to 2014
Line of best fit: y = 0.93x + 6.71
R^2 value: 0.94

Seasonal DNI Comparison





December 2014 - DNI

Line of best fit: y = 0.91x + 38.25

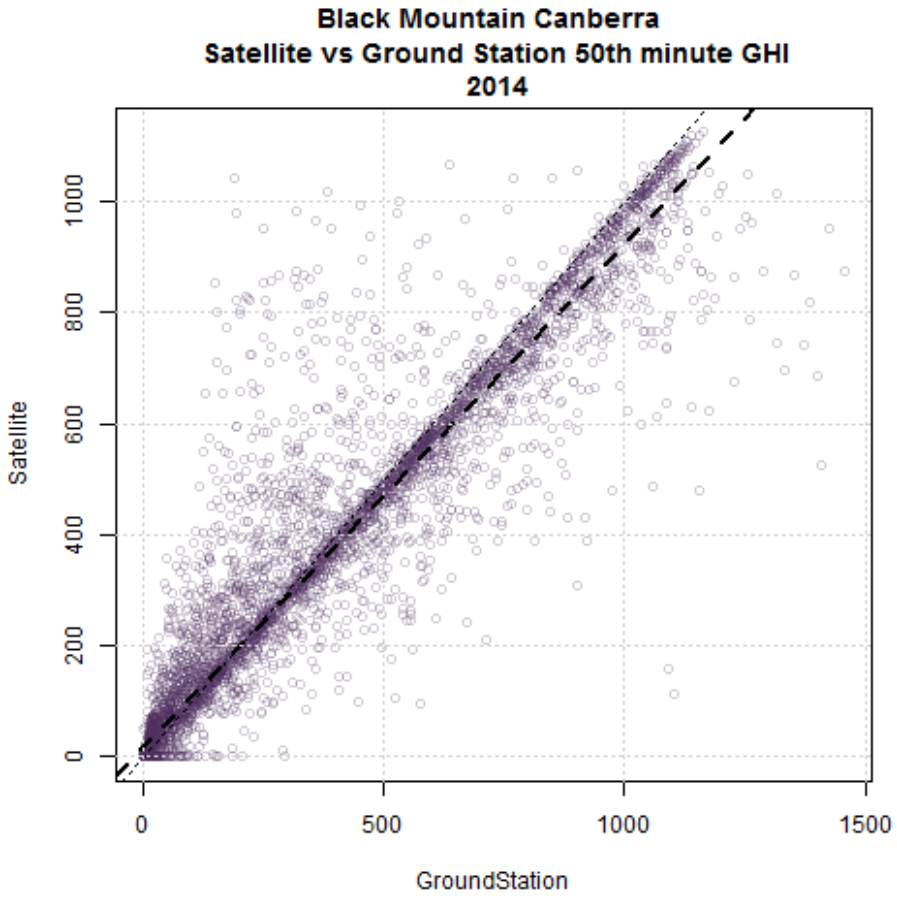
R^2 value: 0.91

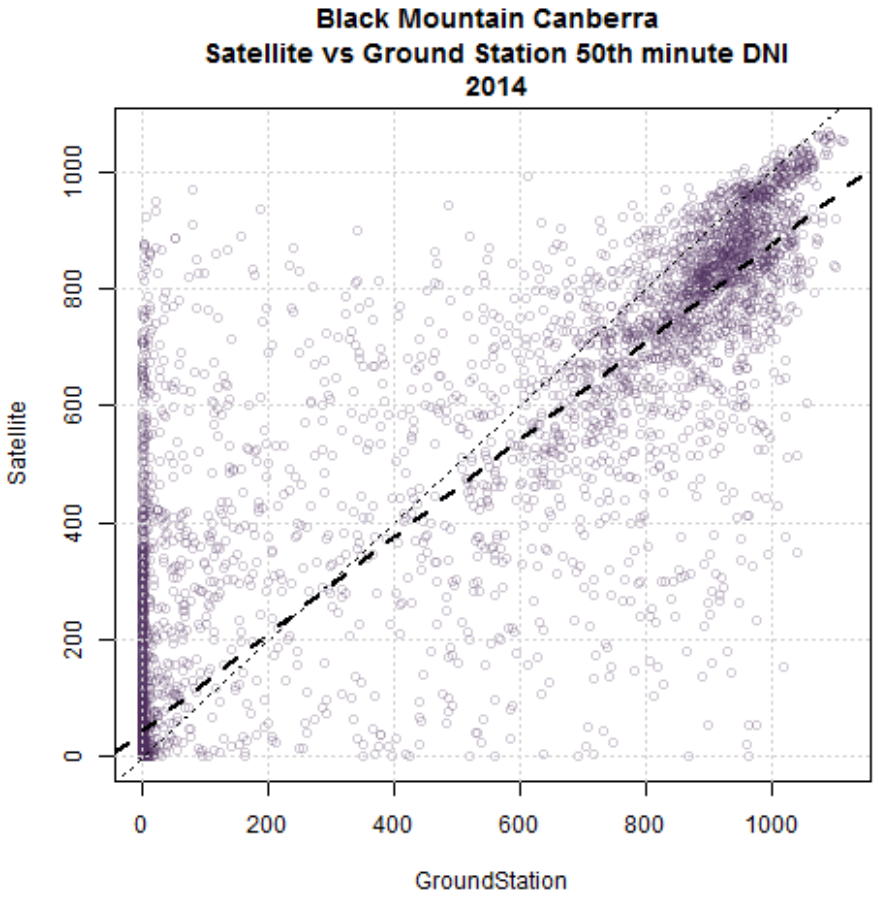
June 2014 - DNI

Line of best fit: y = 0.84x + 27.55

R^2 value: 0.81

Hourly 50th minute Comparison

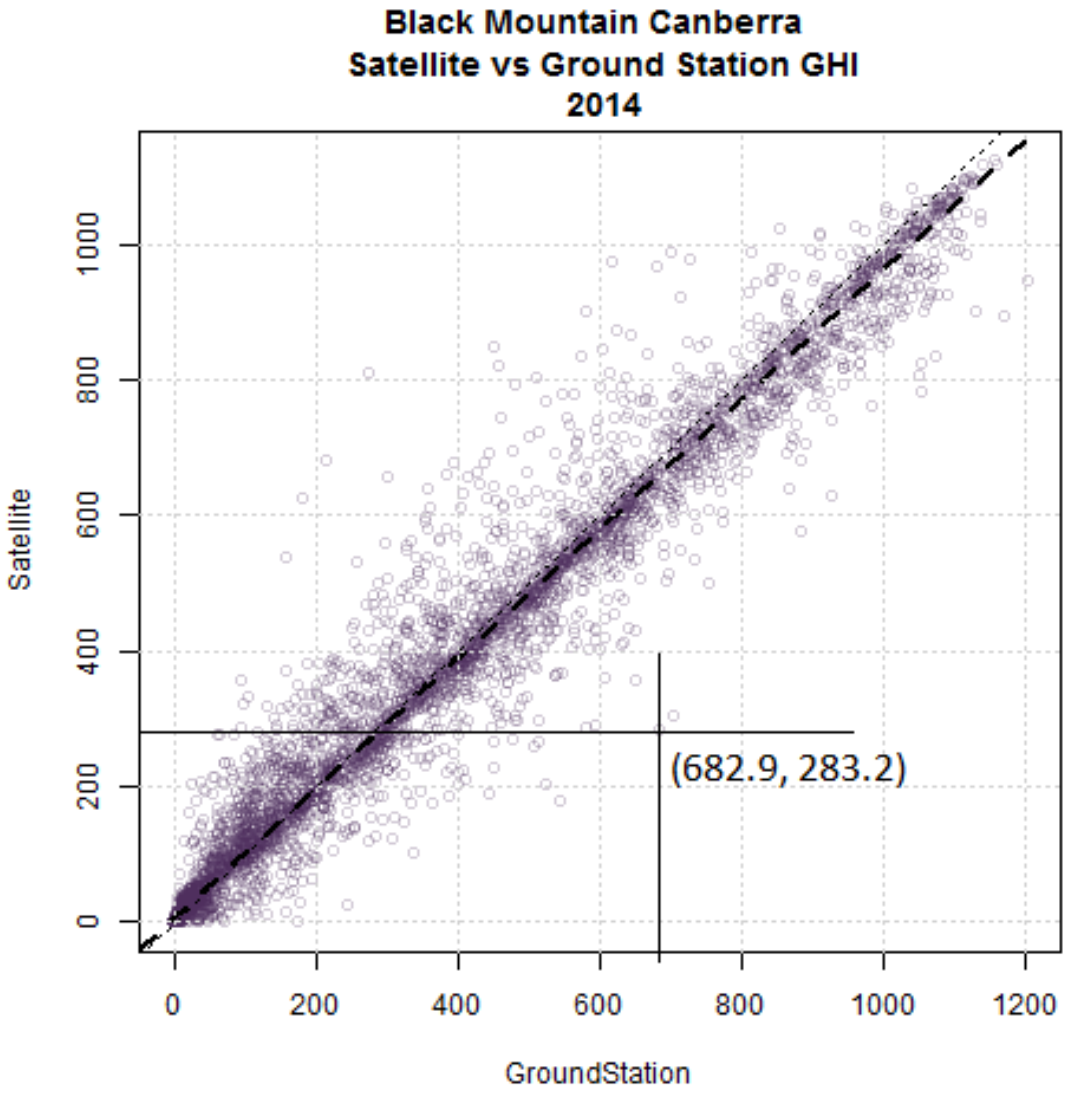




2014 Whole Year – Global (GHI)
Line of best fit: y = 0.91x + 17.16
R^2 value: 0.92

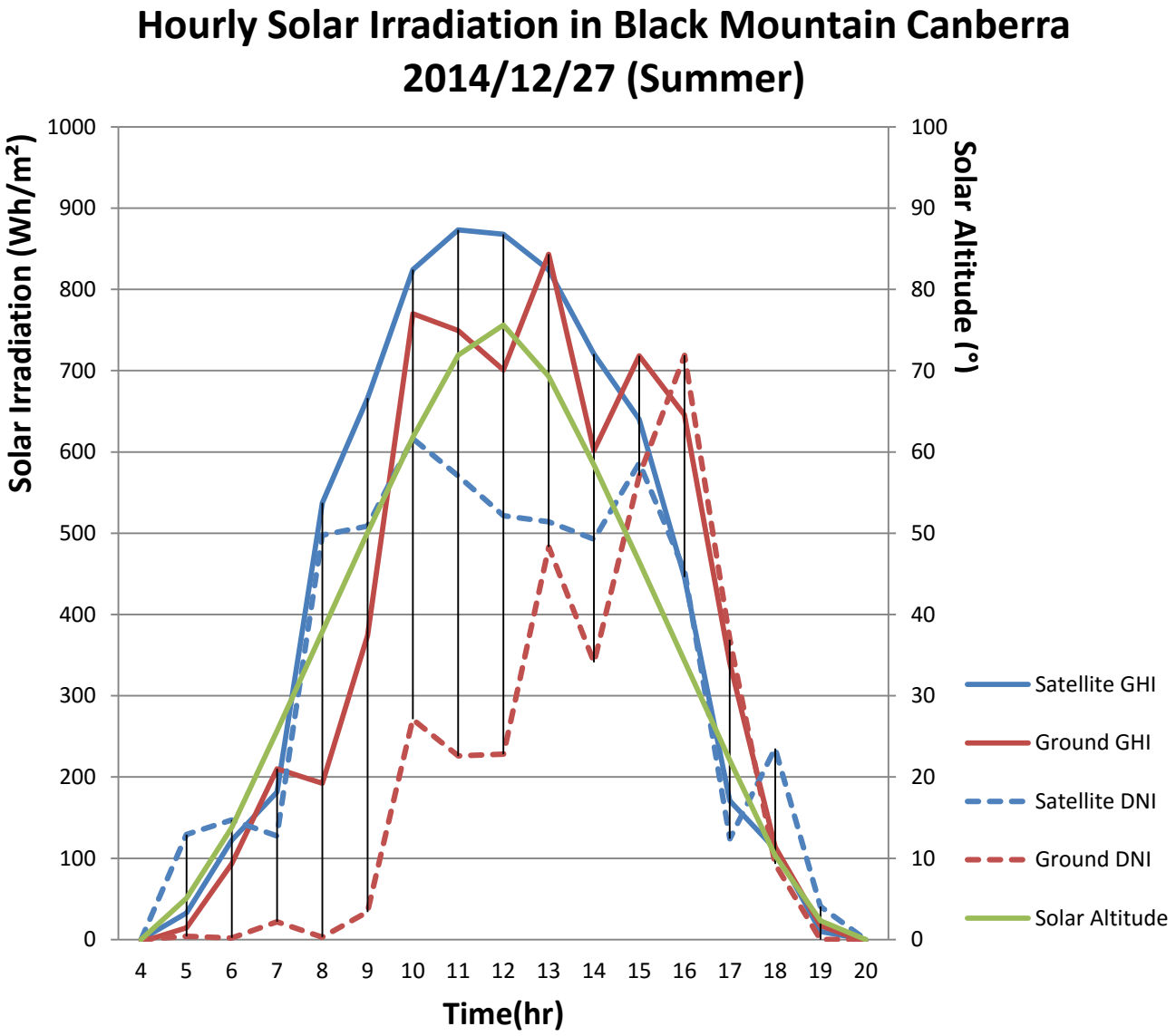
2014 Whole Year – Direct (DNI)
Line of best fit: y = 0.83x + 42.28
R^2 value: 0.83

Outlier Analysis – Spring example

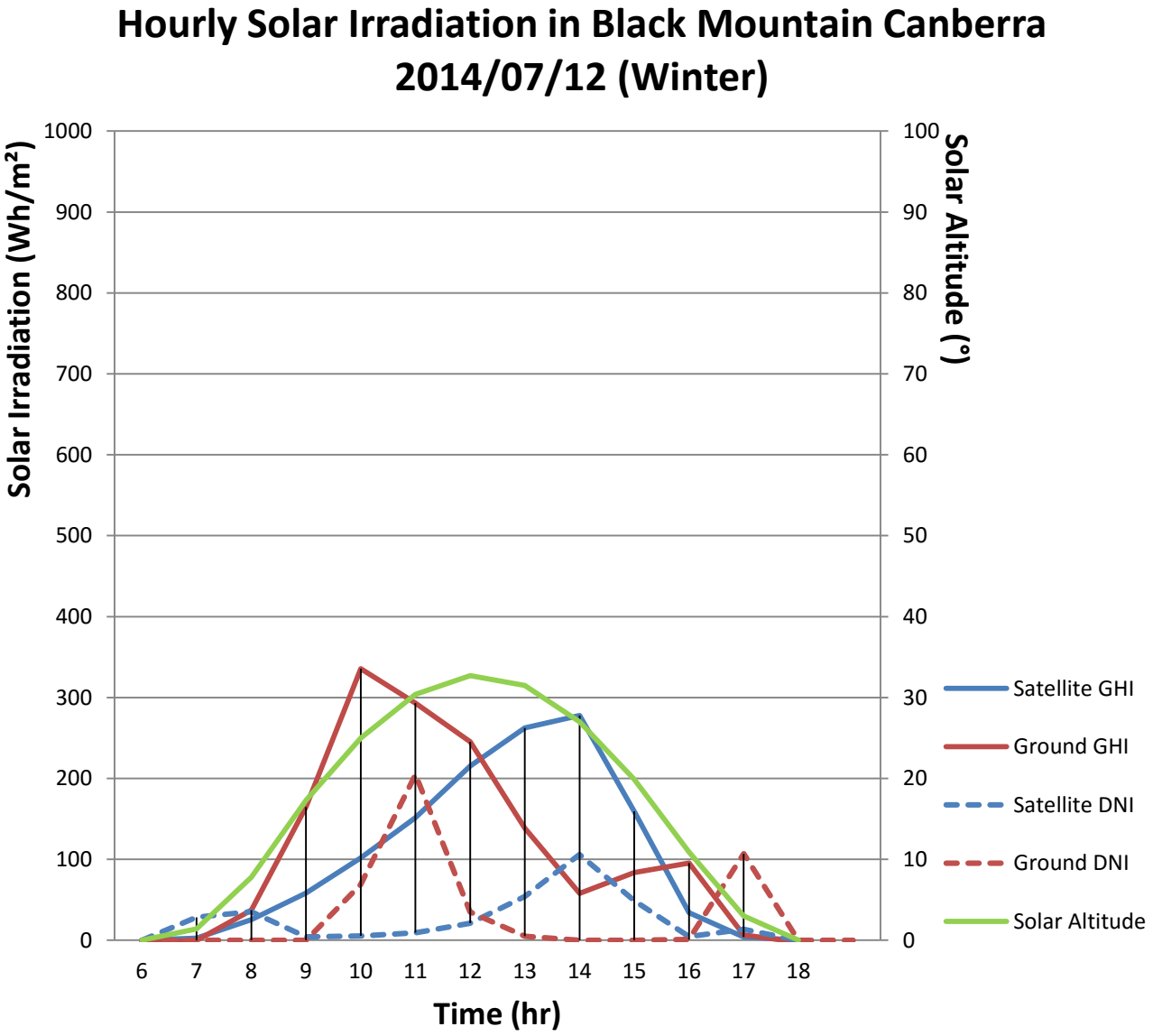


Sample outlier occurred at 2014-09-16 13:00:00 AEST (2014-09-16 03:00:00 UTC)

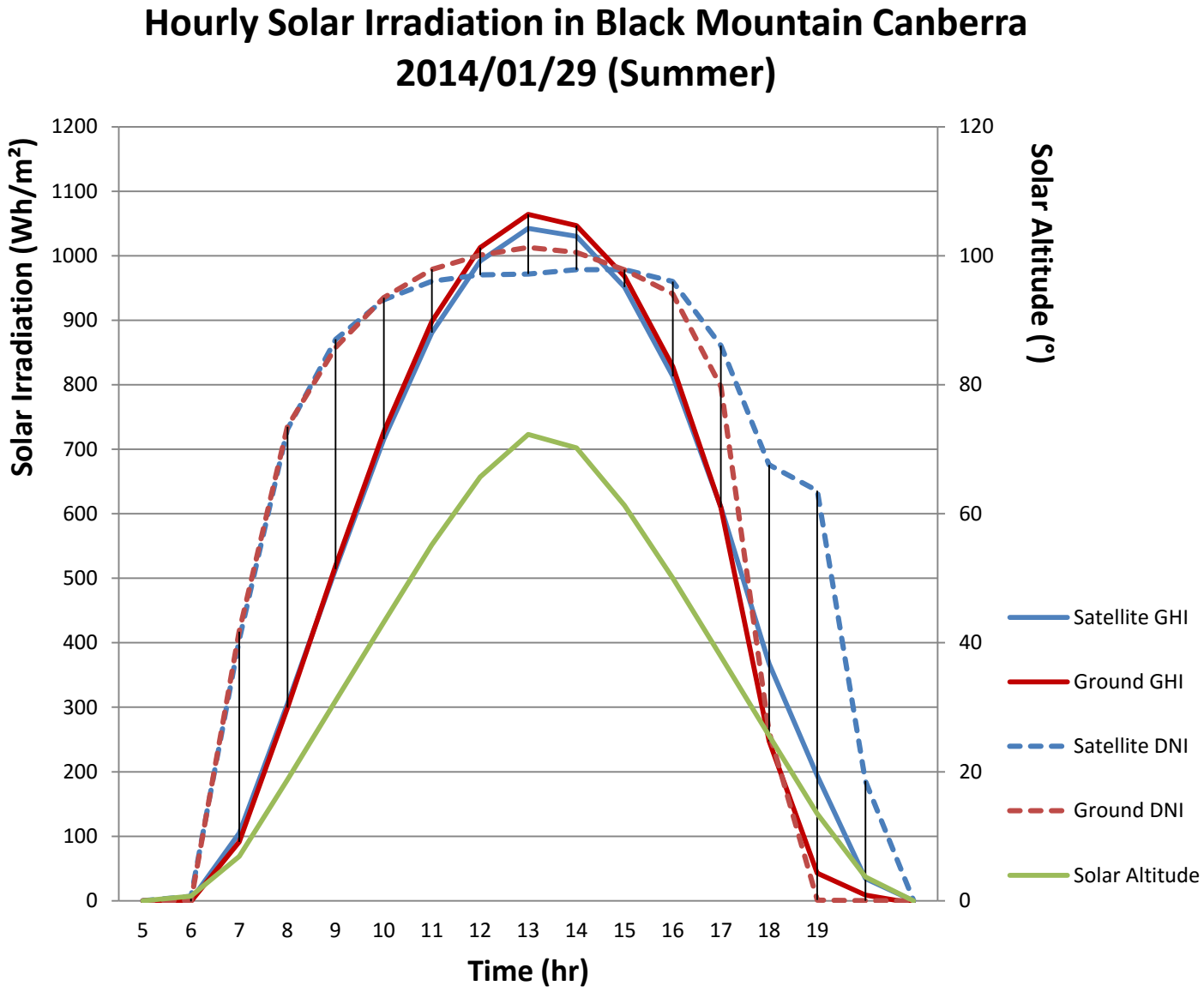
Outliers GHI



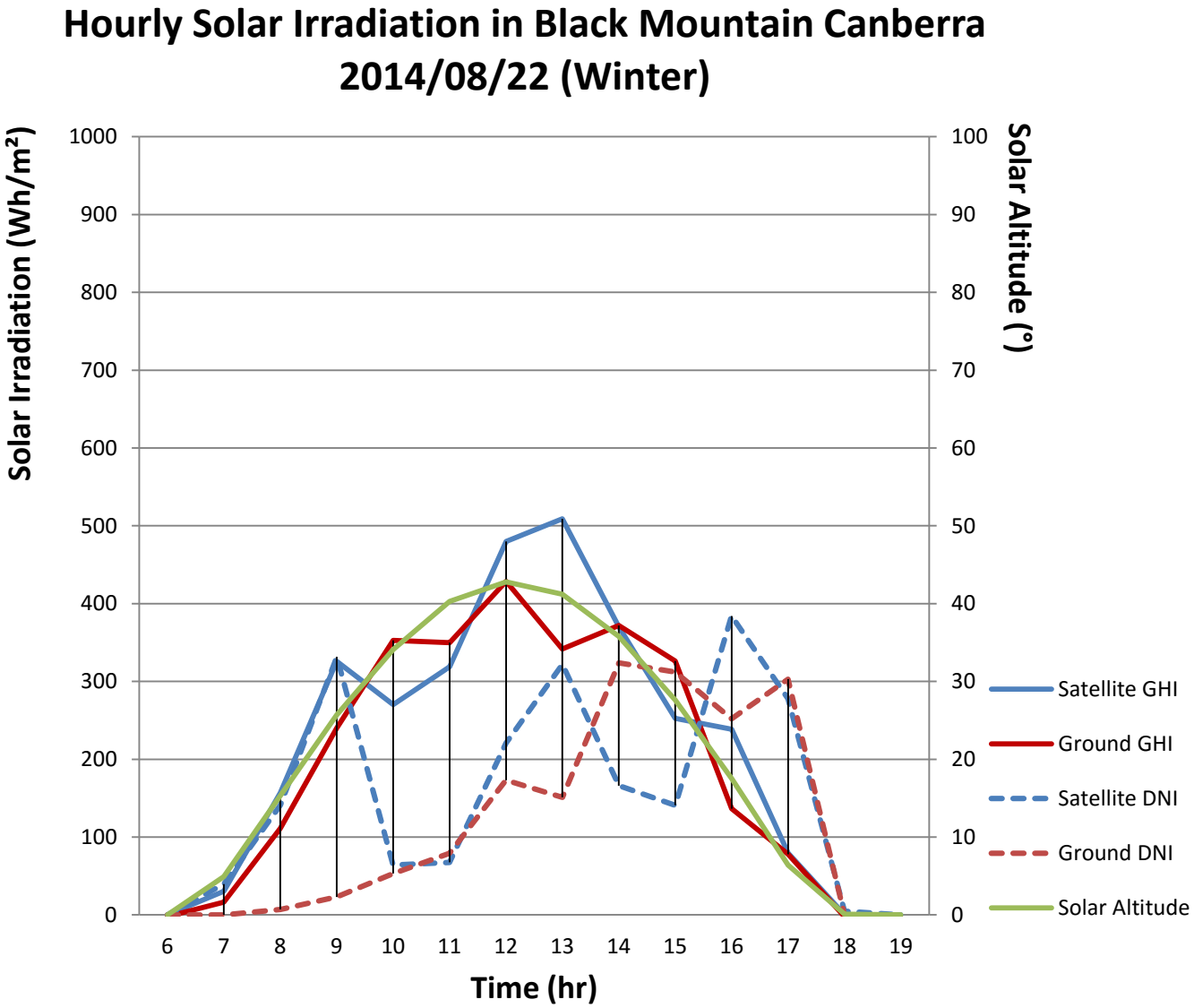
Outliers GHI



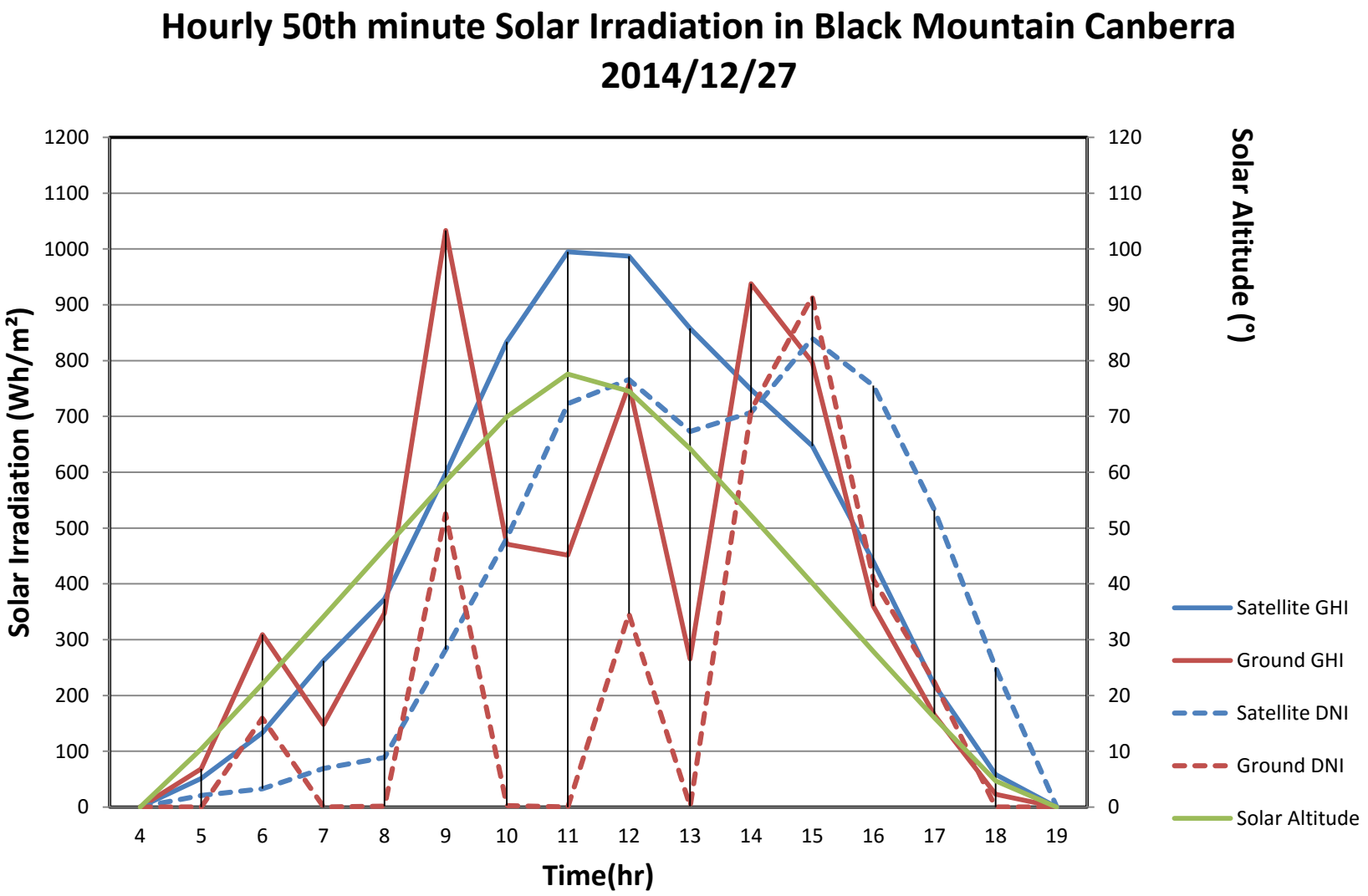
Outliers DNI



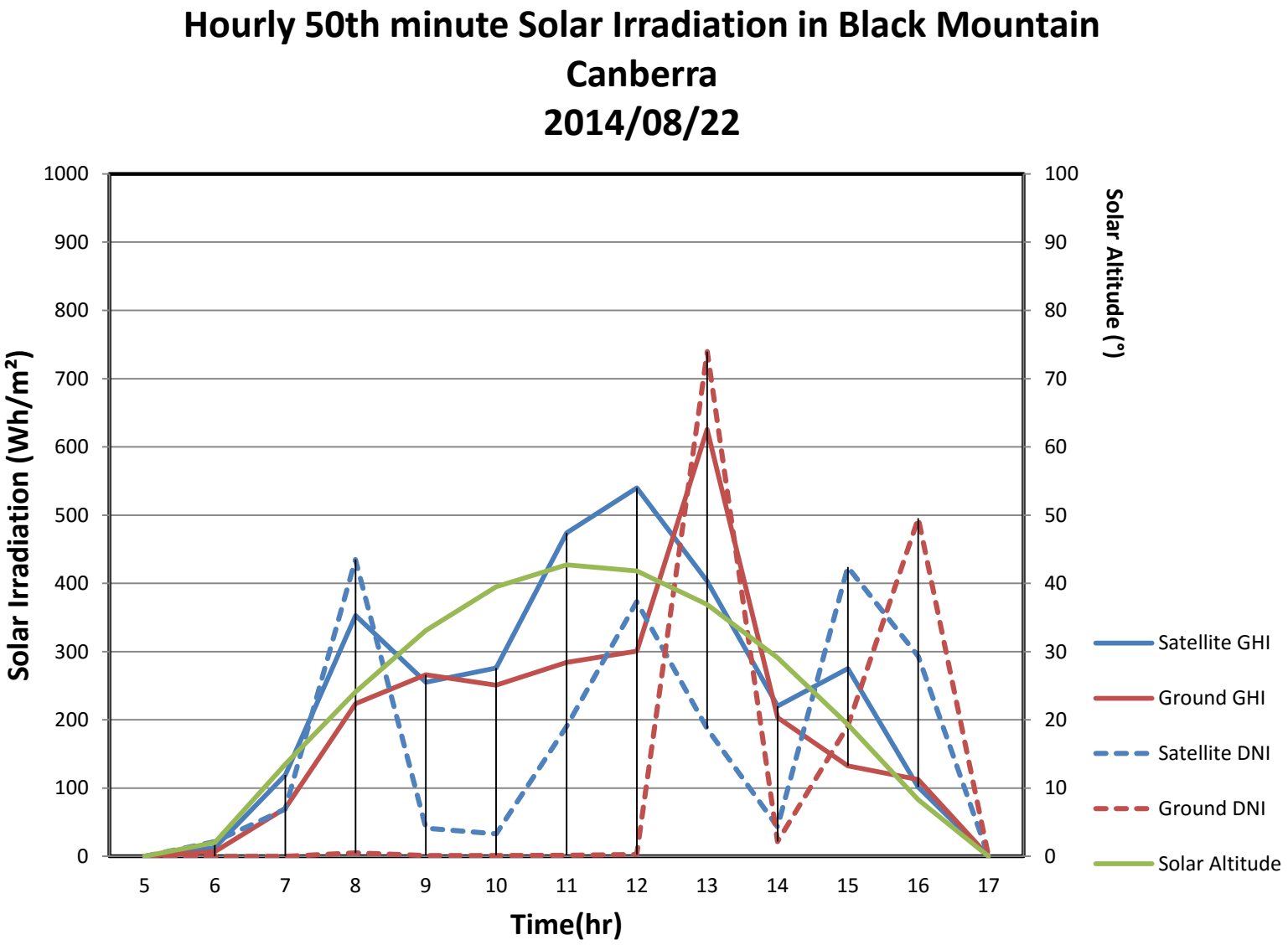
Outliers DNI



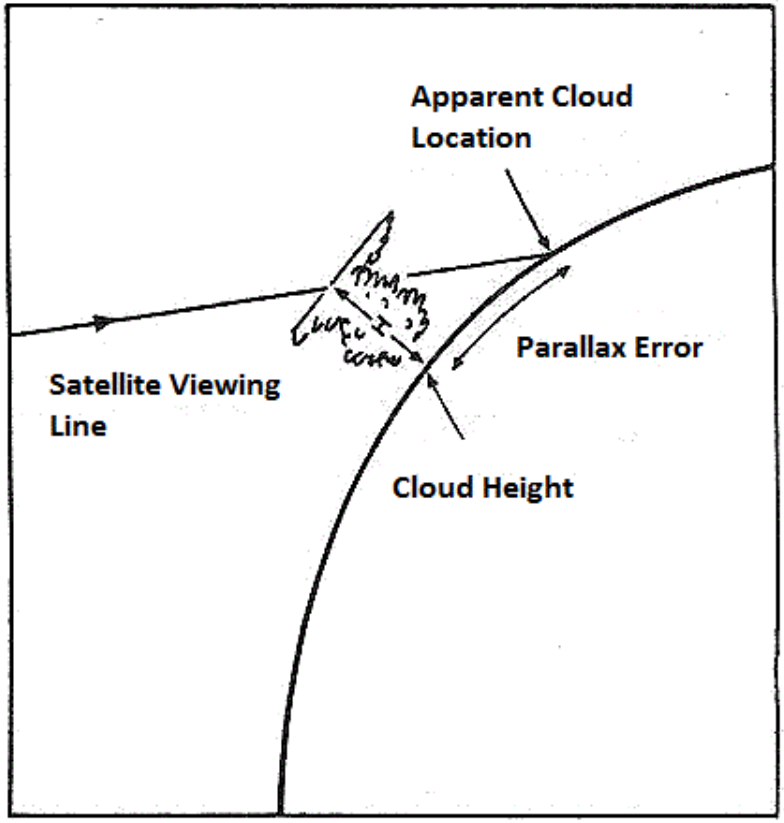
Outliers 50th minute

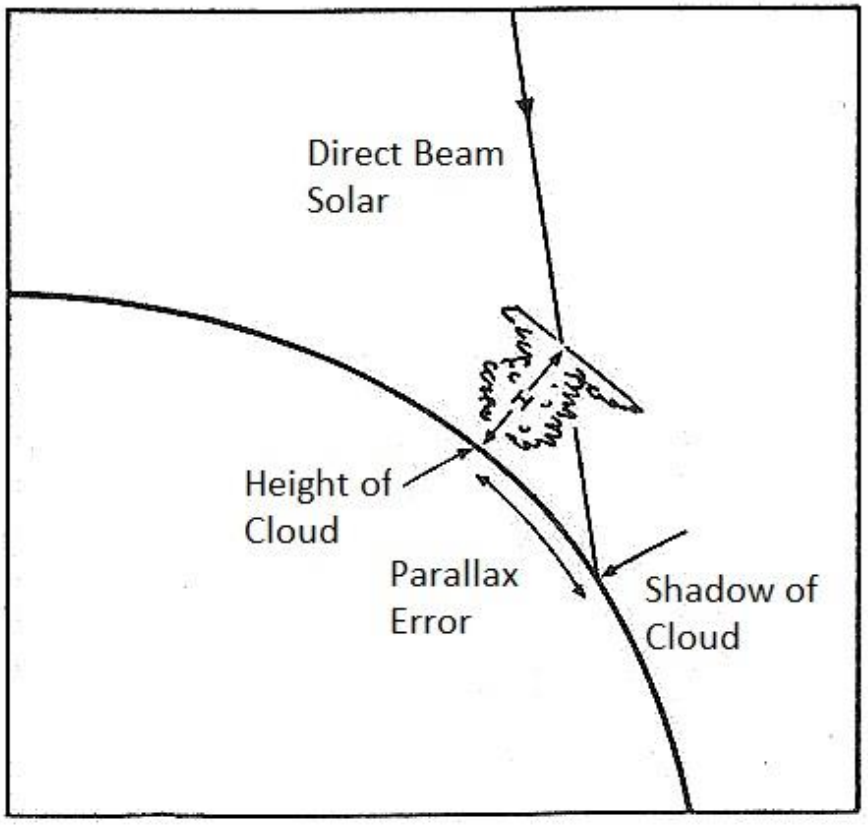


Outliers 50th minute

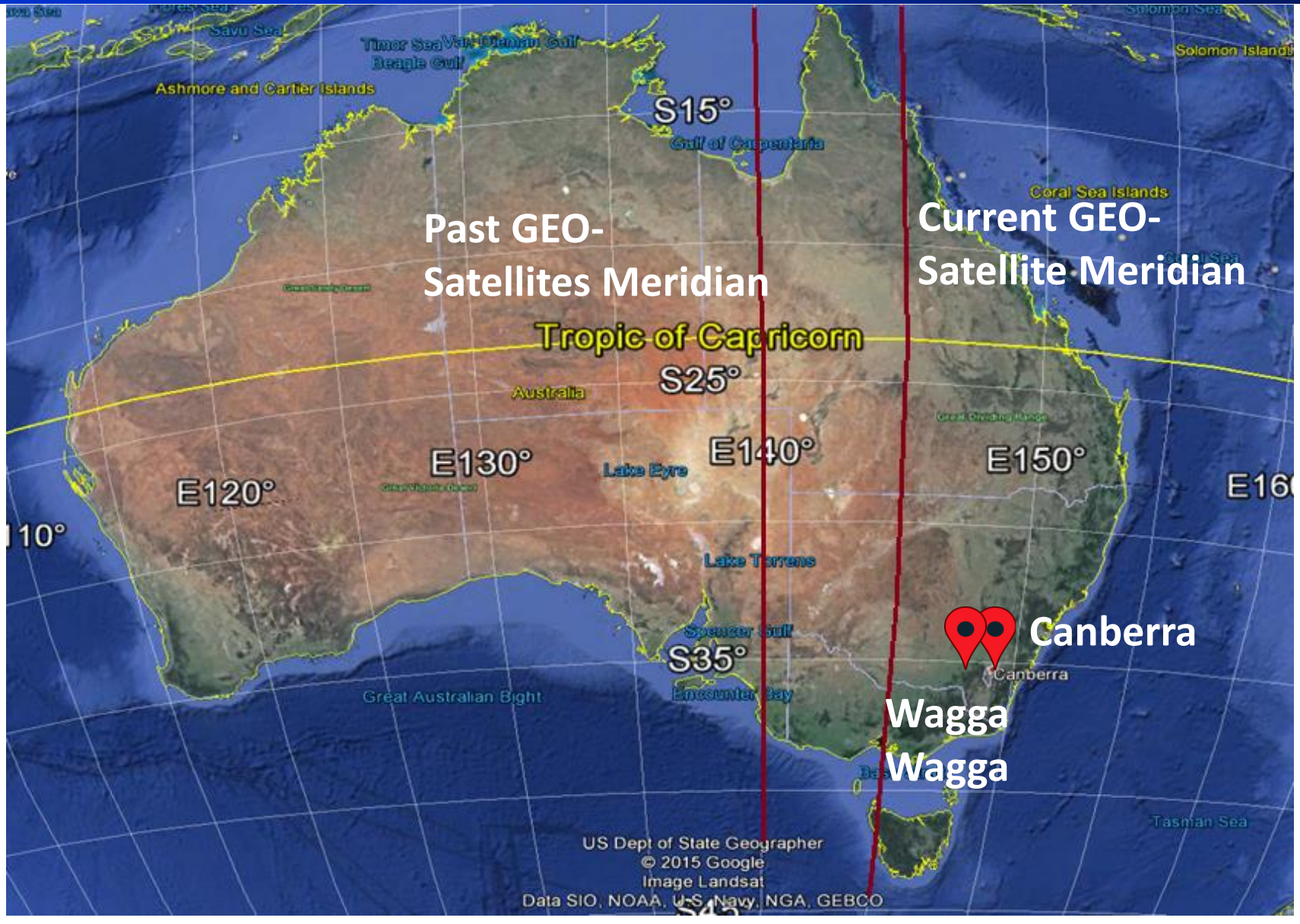


Parallax Error – satellite and solar

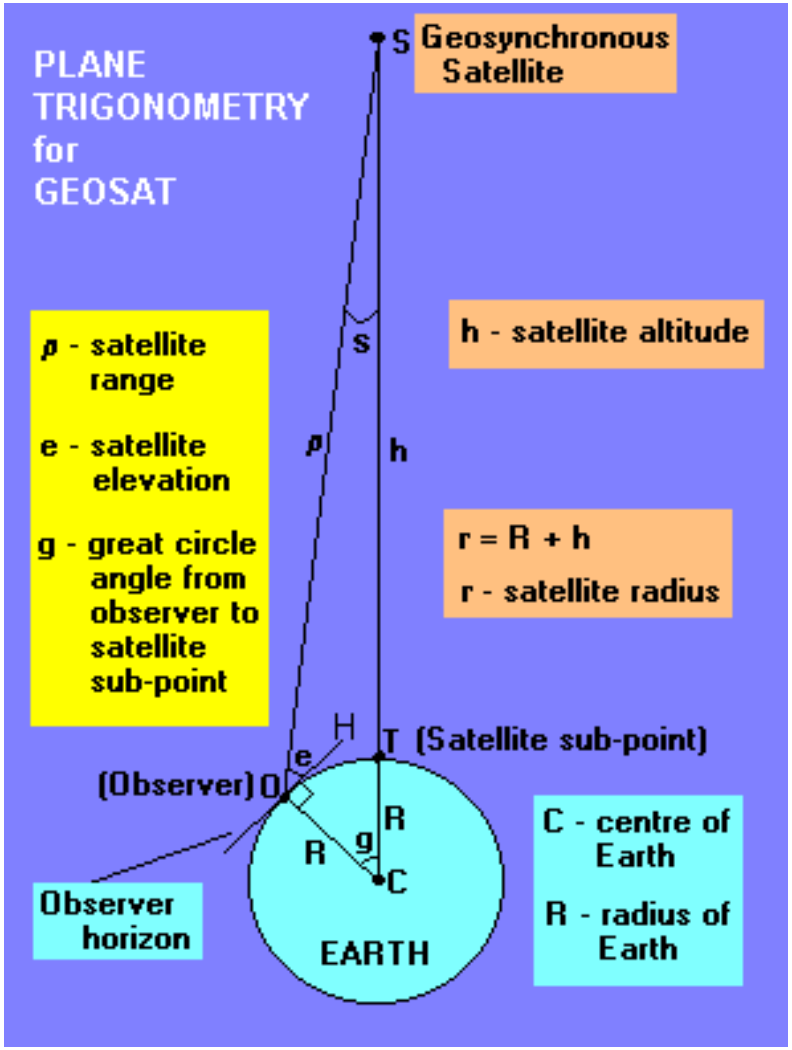




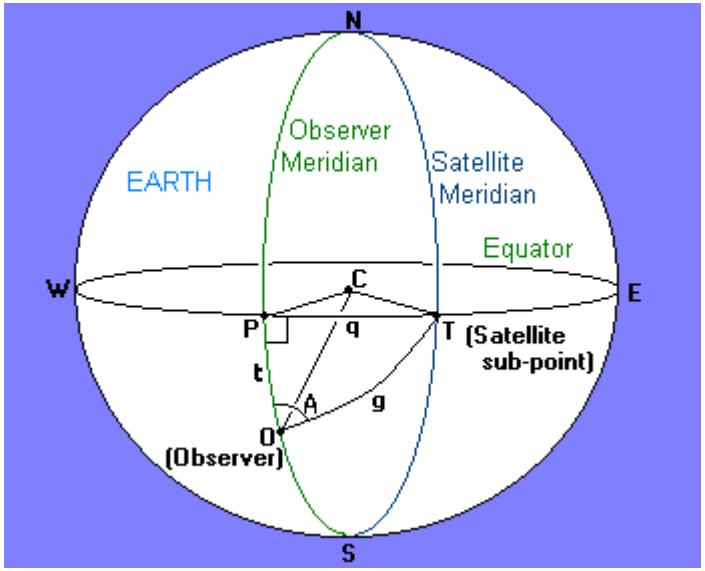
Parallax Error – satellite view angle



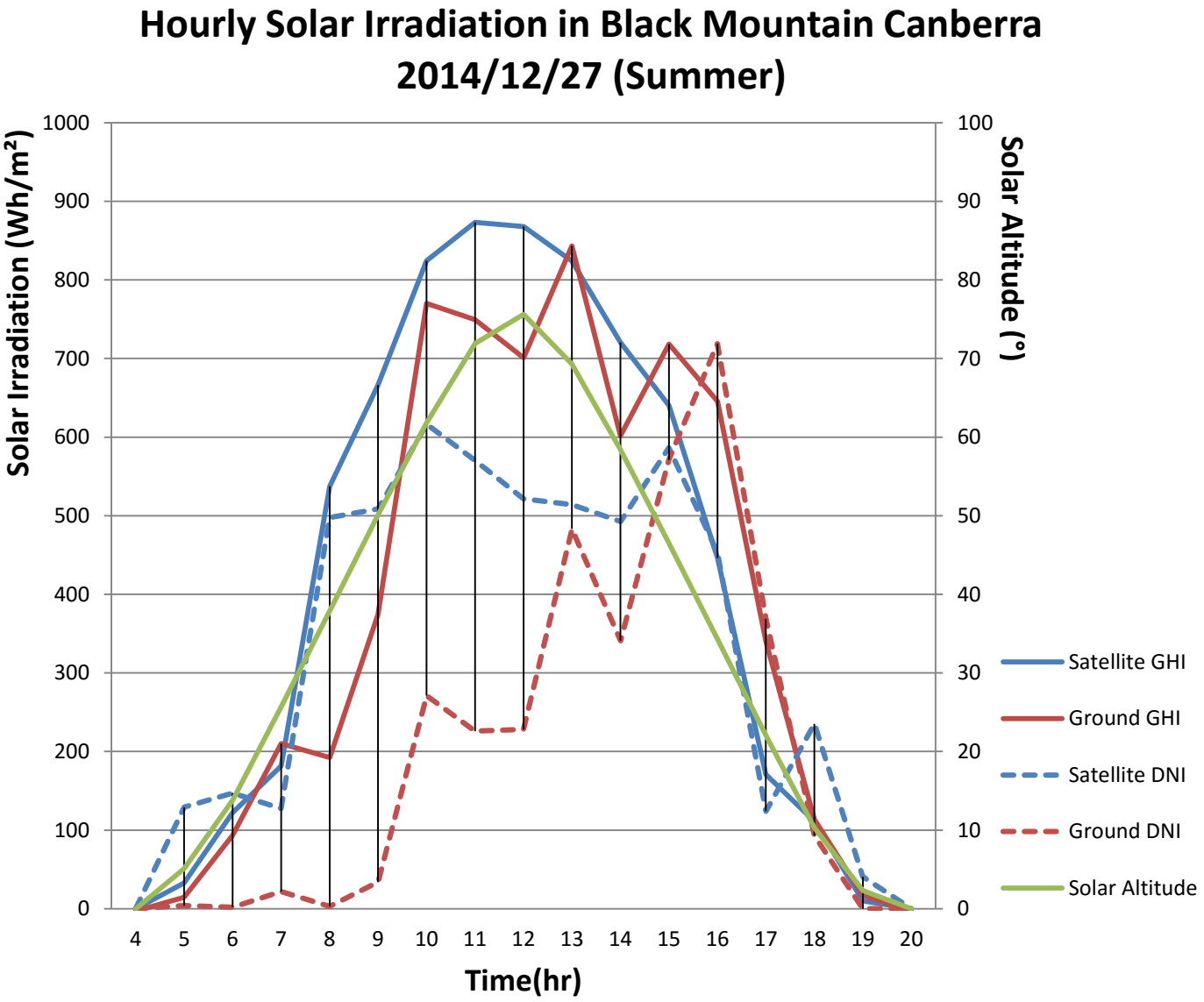
Satellite Parallax Error

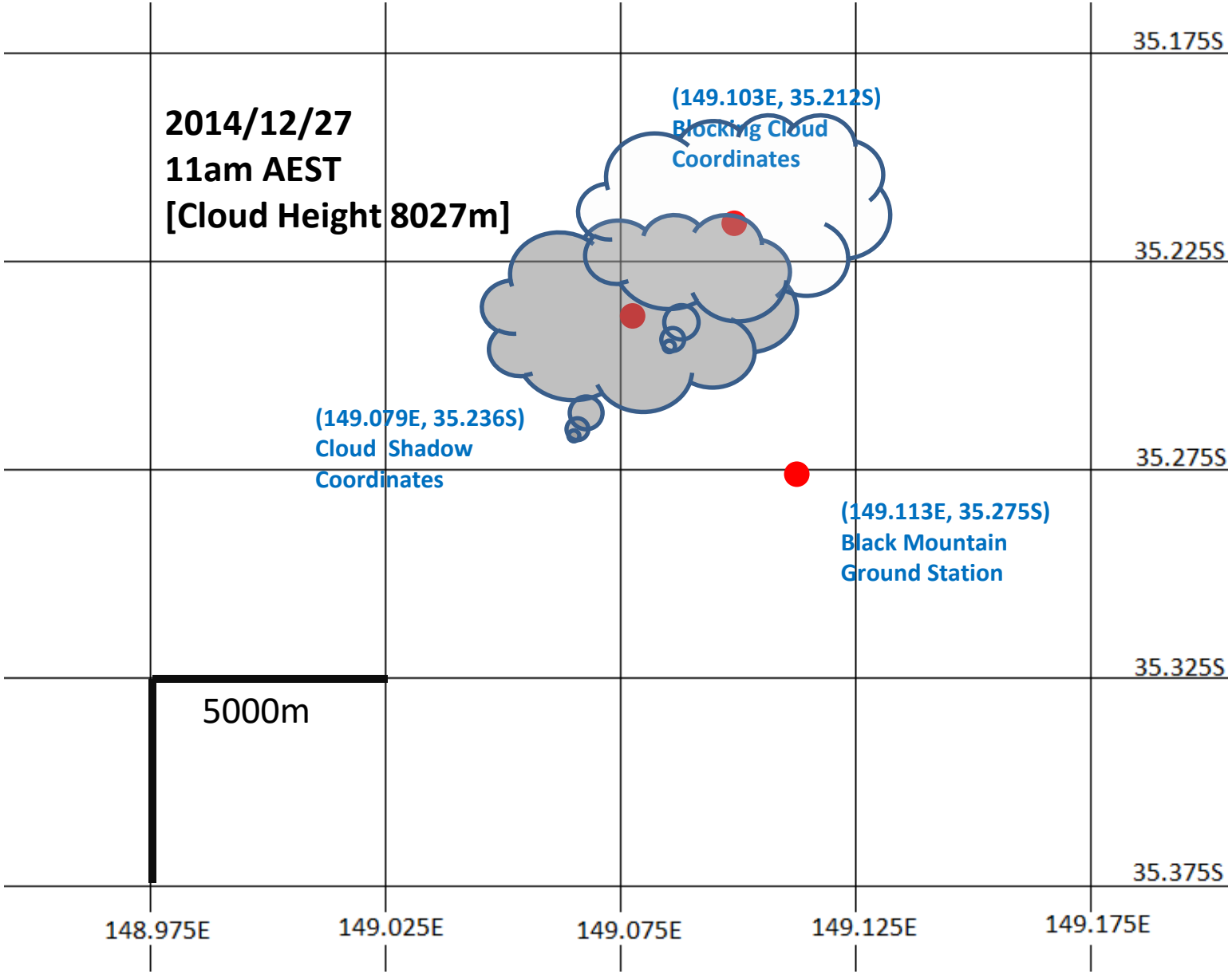


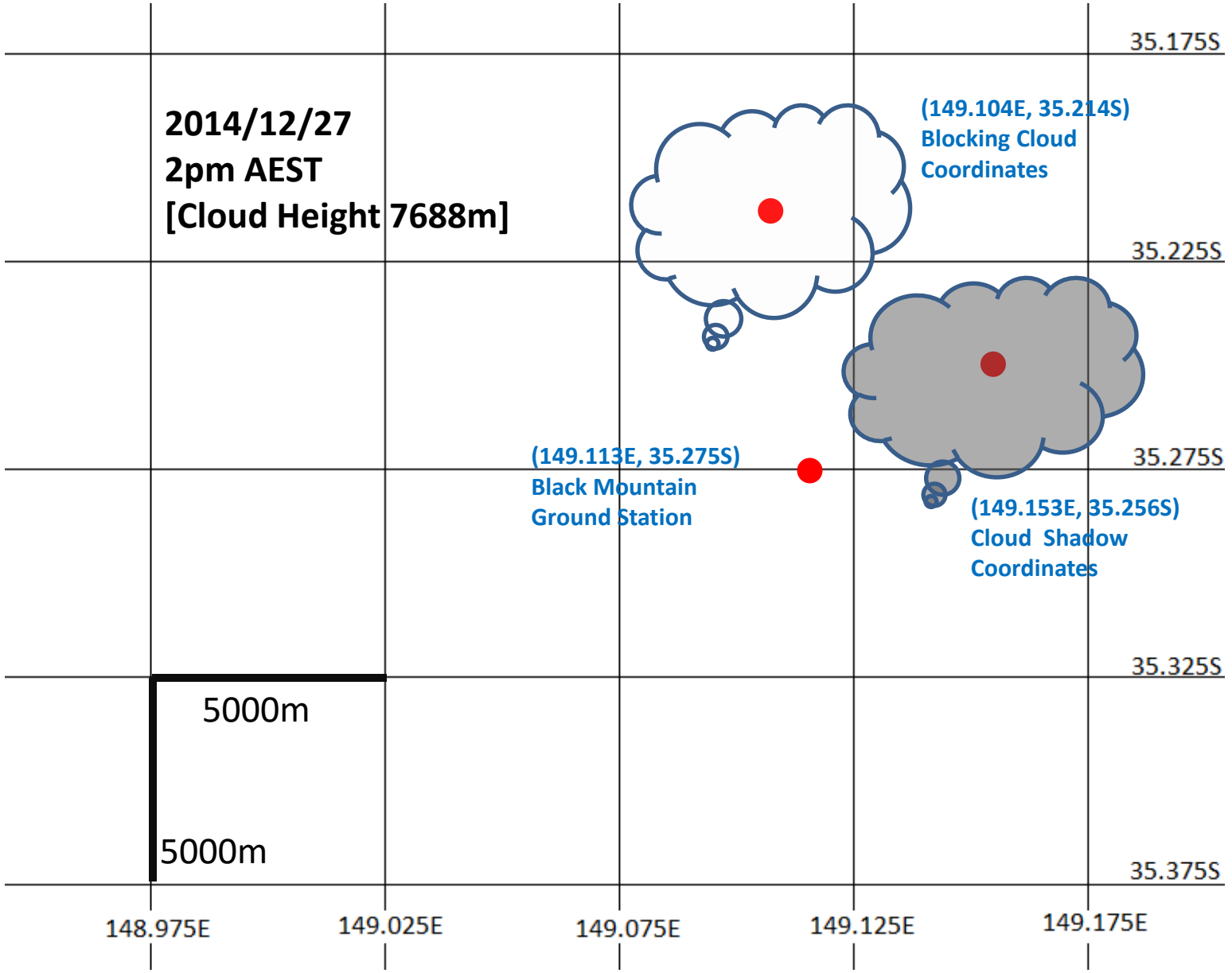
Planar trigonometry (where the site lies close to the satellite meridian) and 3D trigonometry (below) for all other cases.

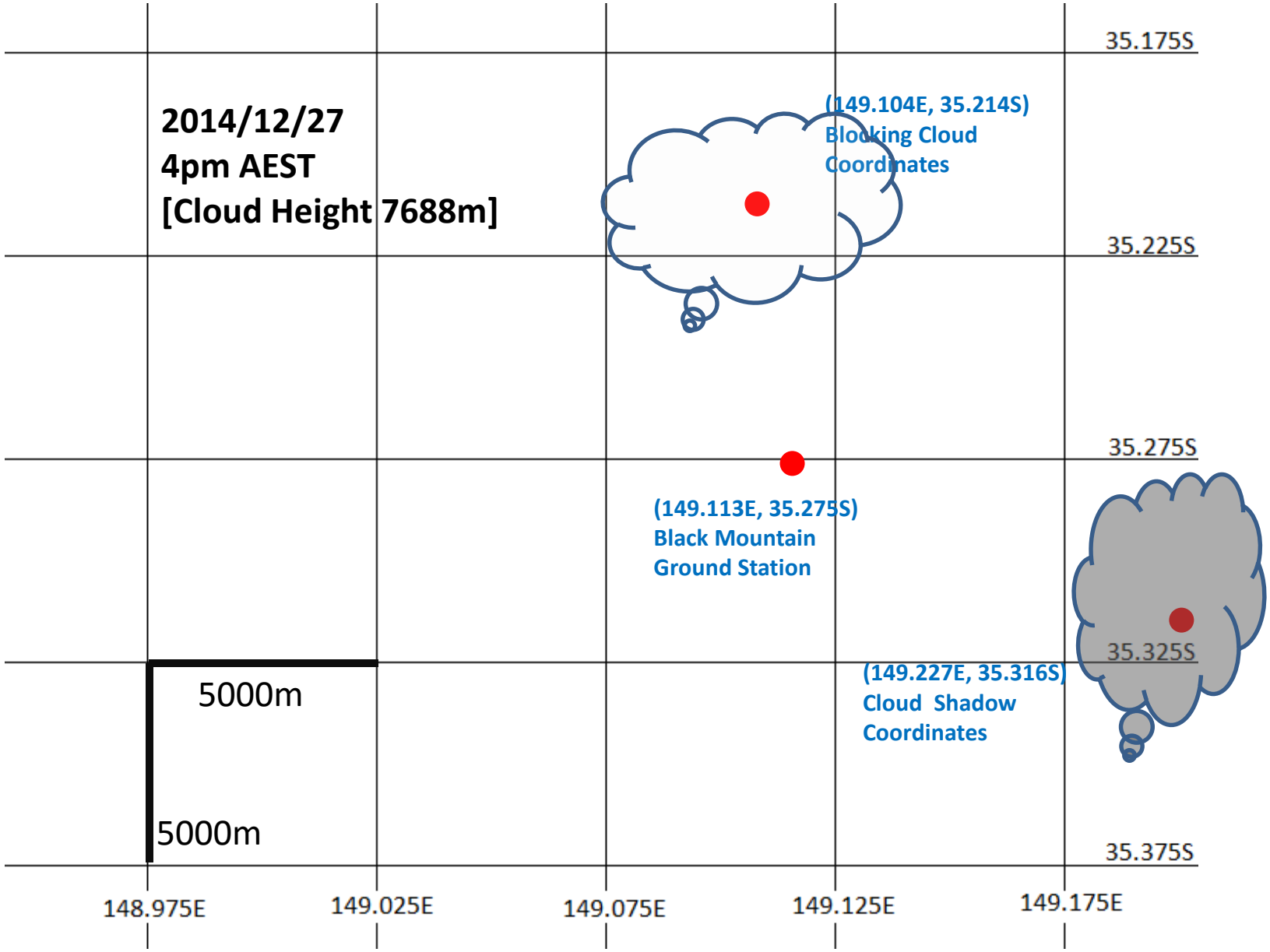


Satellite and Solar Parallax Errors

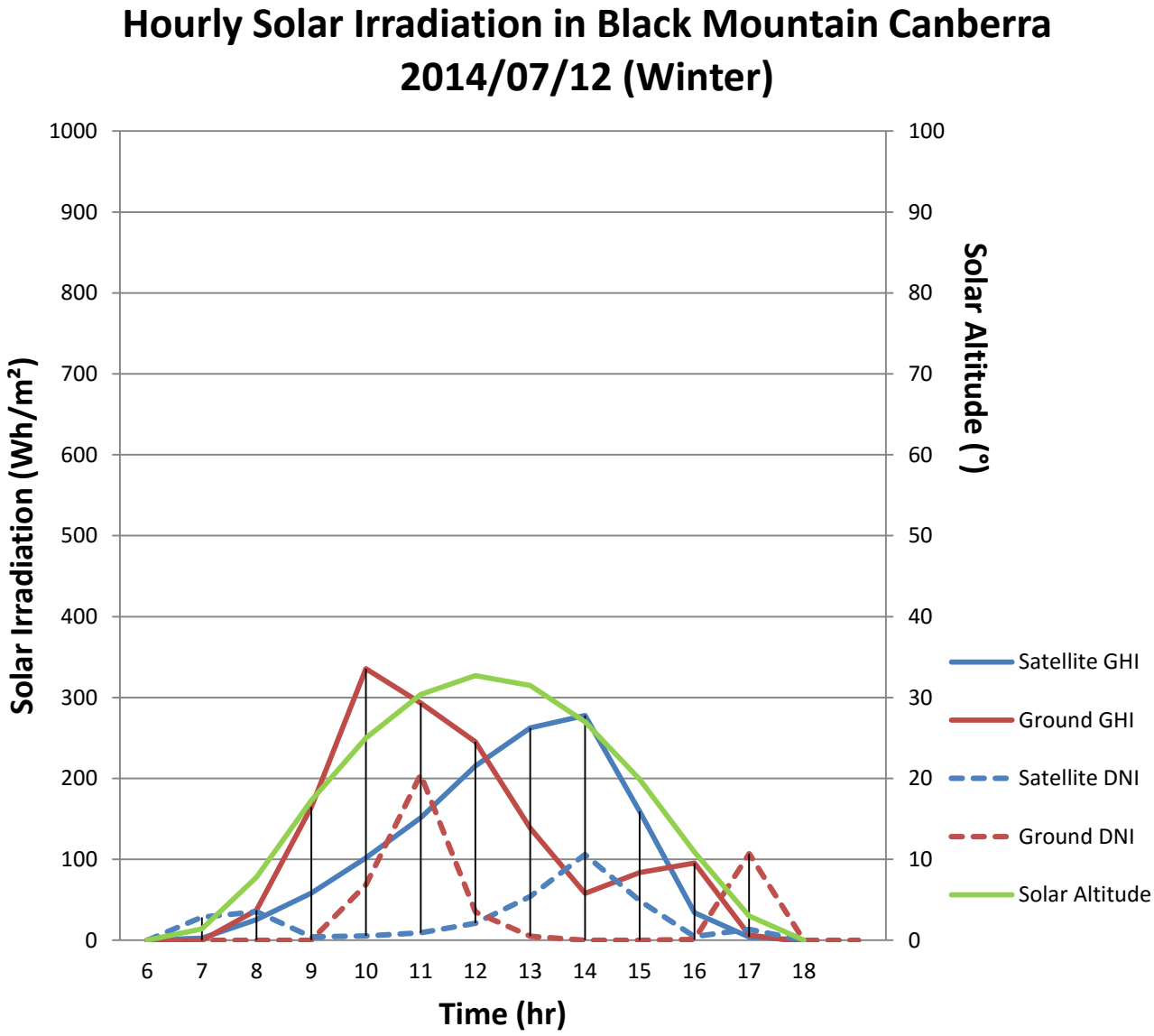



2014/12/27
11am AEST
[Cloud Height 8027m]
(149.103E, 35.212S)
Blocking Cloud
Coordinates
(149.079E, 35.236S)
Cloud Shadow
Coordinates
(149.113E, 35.275S)
Black Mountain
Ground Station
5000m
35.175S
35.225S
35.275S
35.325S
35.375S
148.975E
149.025E
149.075E
149.125E
149.175E

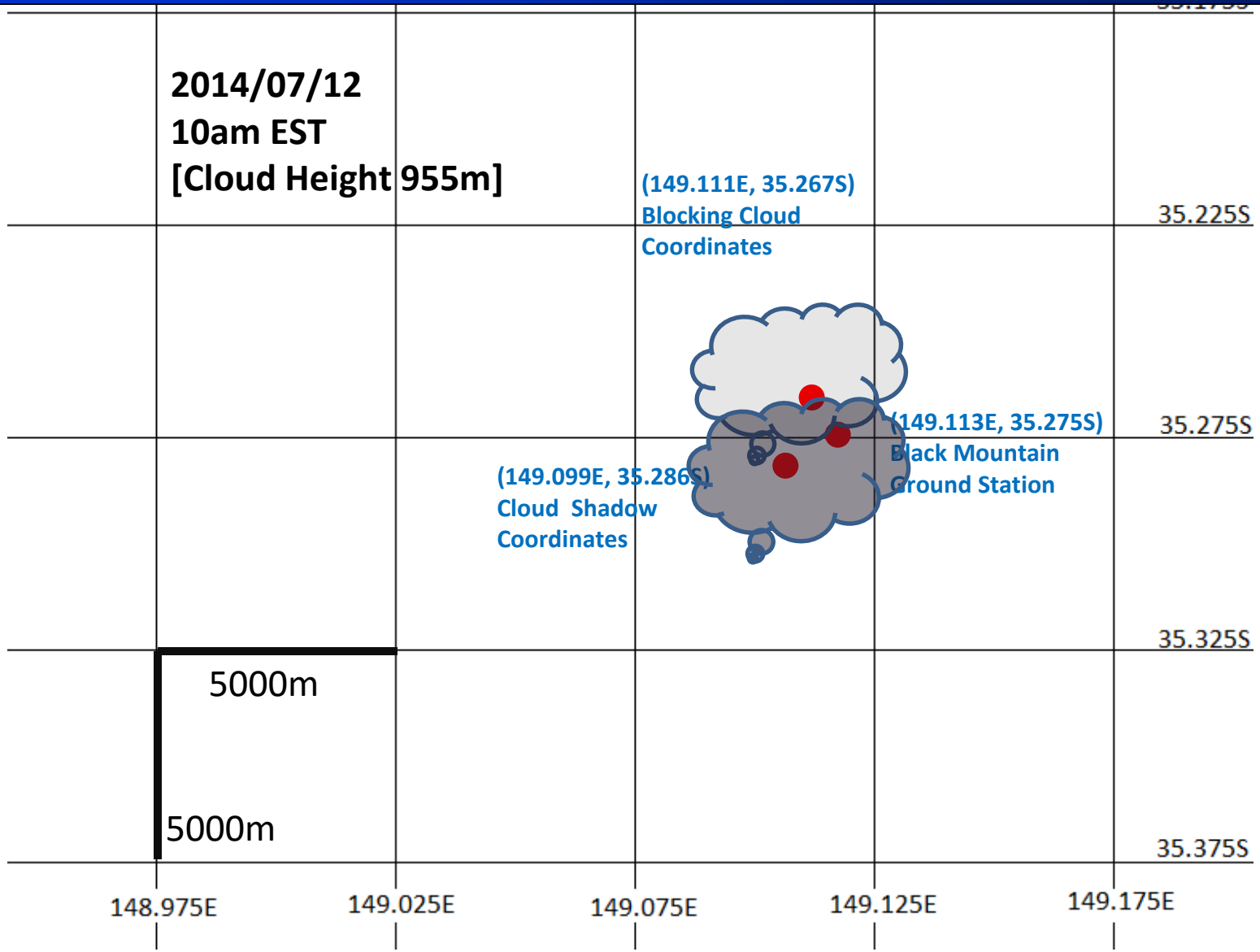

2014/12/27
2pm AEST
[Cloud Height 7688m]
(149.104E, 35.214S)
Blocking Cloud
Coordinates
(149.113E, 35.275S)
Black Mountain
Ground Station
(149.153E, 35.256S)
Cloud Shadow
Coordinates
5000m
5000m
35.175S
35.225S
35.275S
35.325S
35.375S
148.975E
149.025E
149.075E
149.125E
149.175E


2014/12/27
4pm AEST
[Cloud Height 7688m]
(149.104E, 35.214S)
Blocking Cloud
Coordinates
(149.113E, 35.275S)
Black Mountain
Ground Station
(149.227E, 35.316S)
Cloud Shadow
Coordinates
5000m
5000m
35.175S
35.225S
35.275S
35.325S
35.375S
148.975E
149.025E
149.075E
149.125E
149.175E

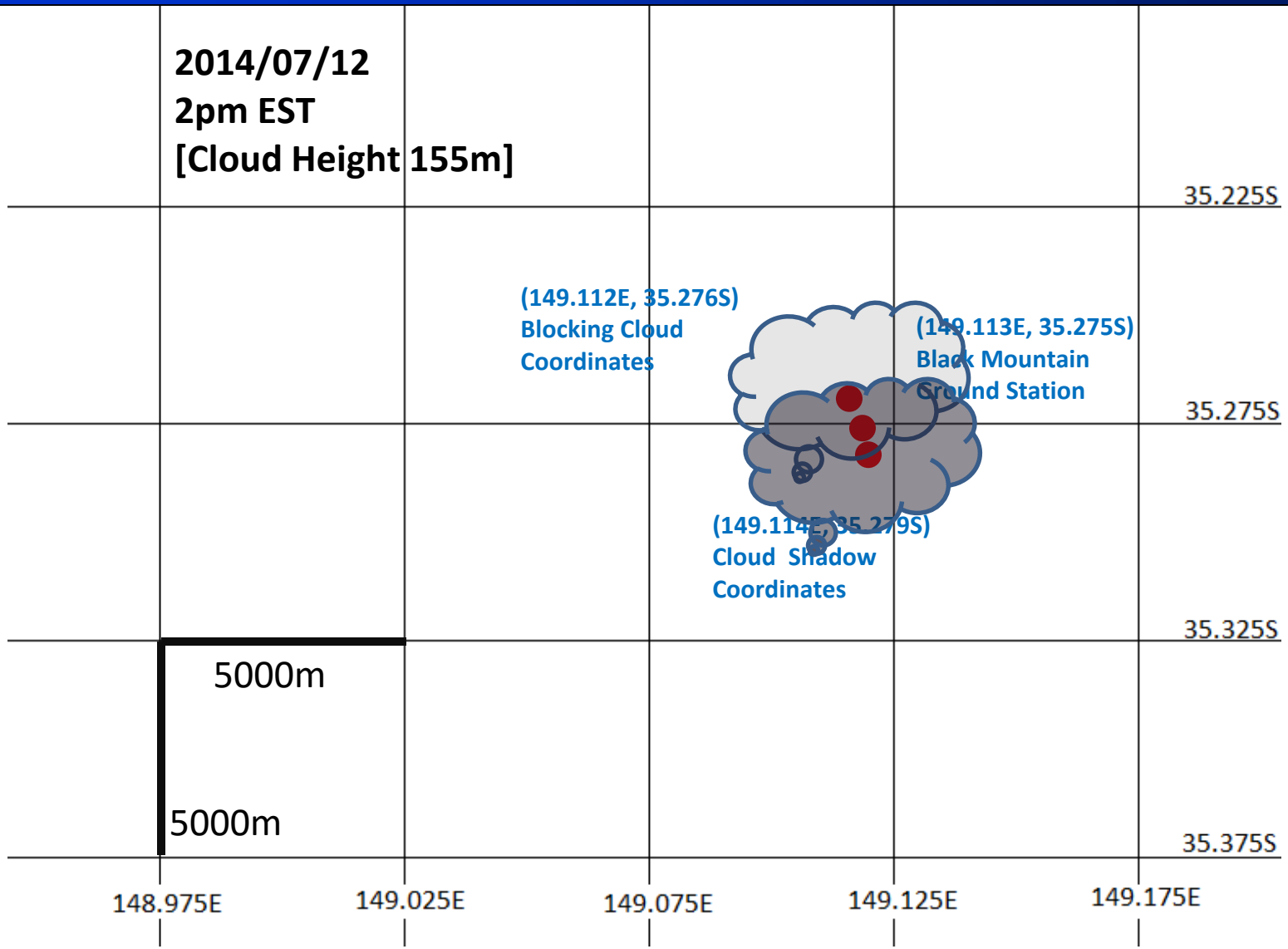
Parallax Error



Parallax Error



Parallax Error



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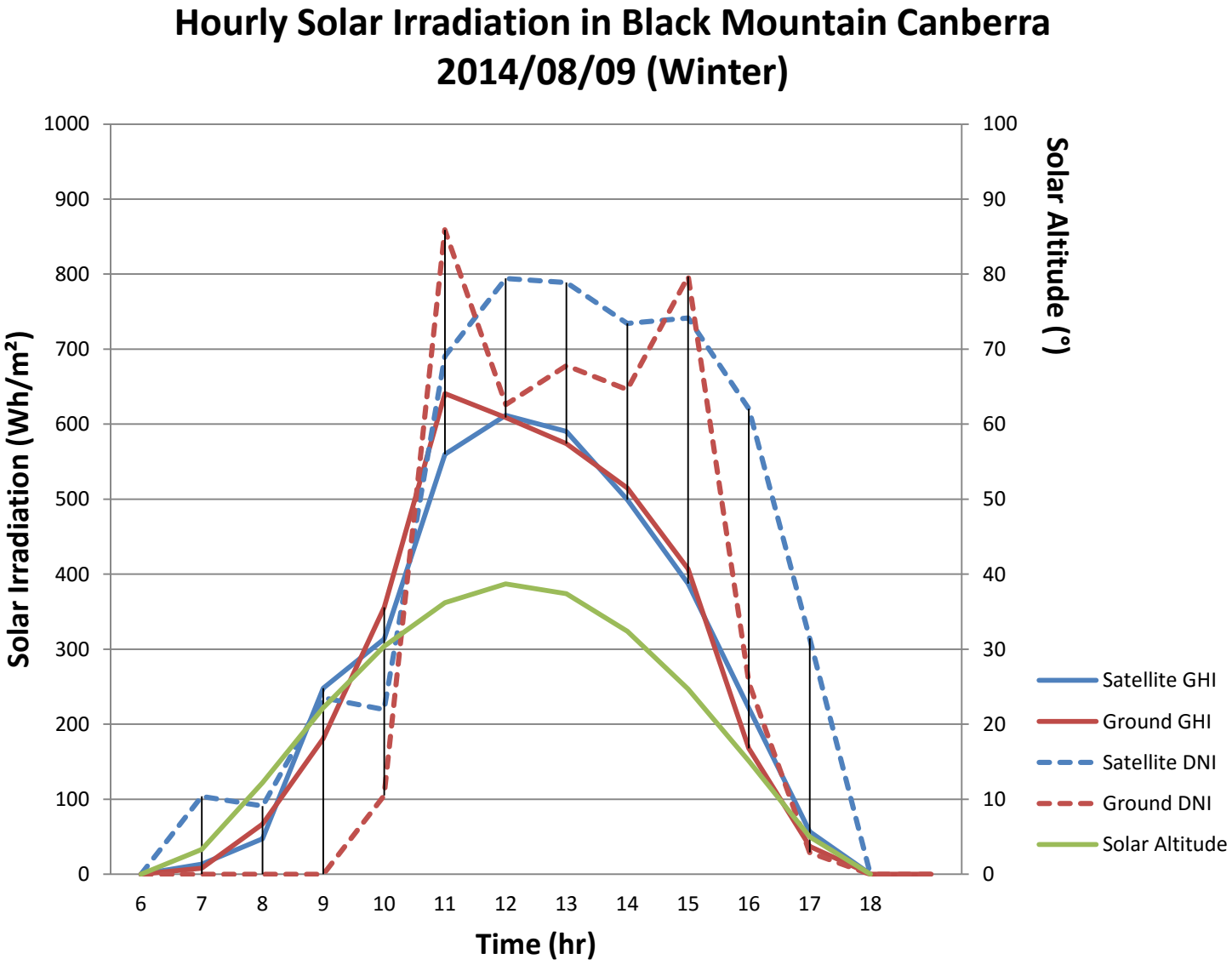

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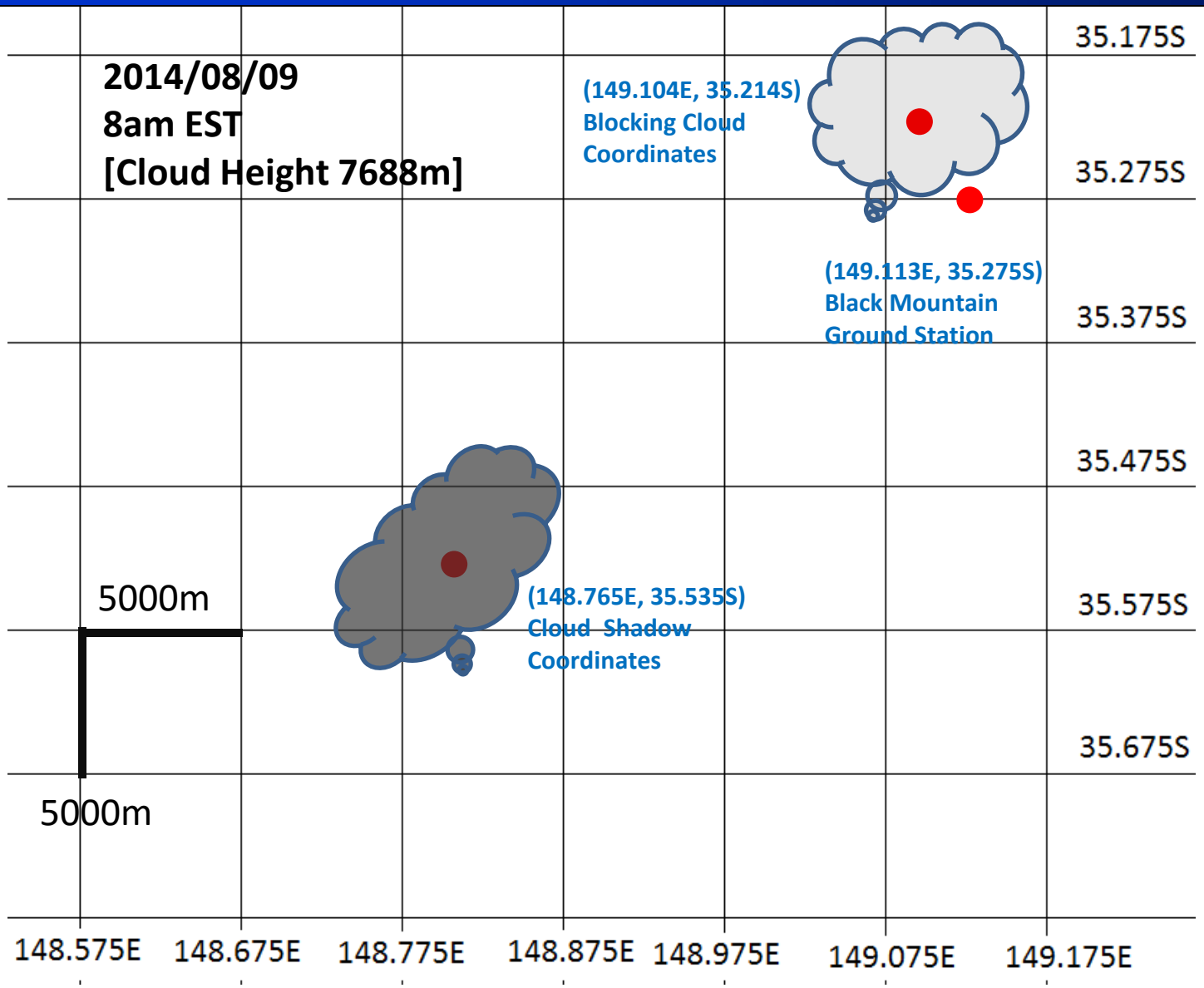
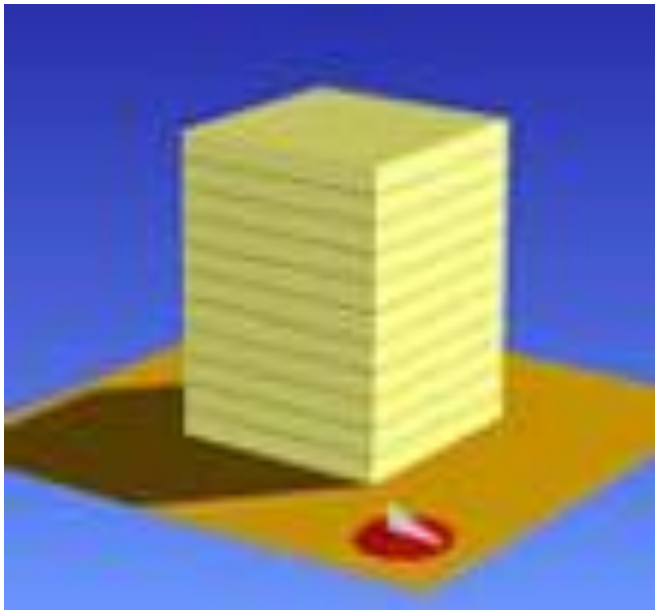
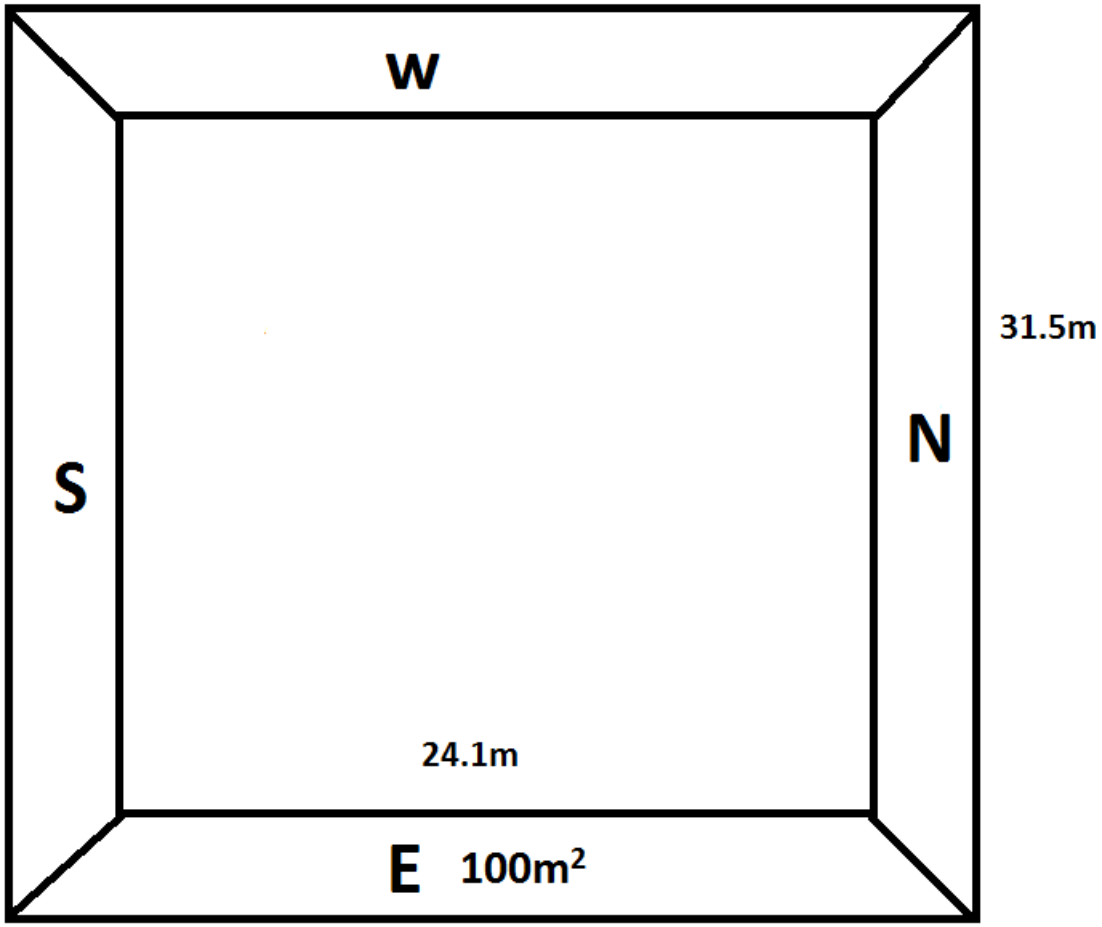


In Application, does it matter?





Heating Energy Consumption 2014

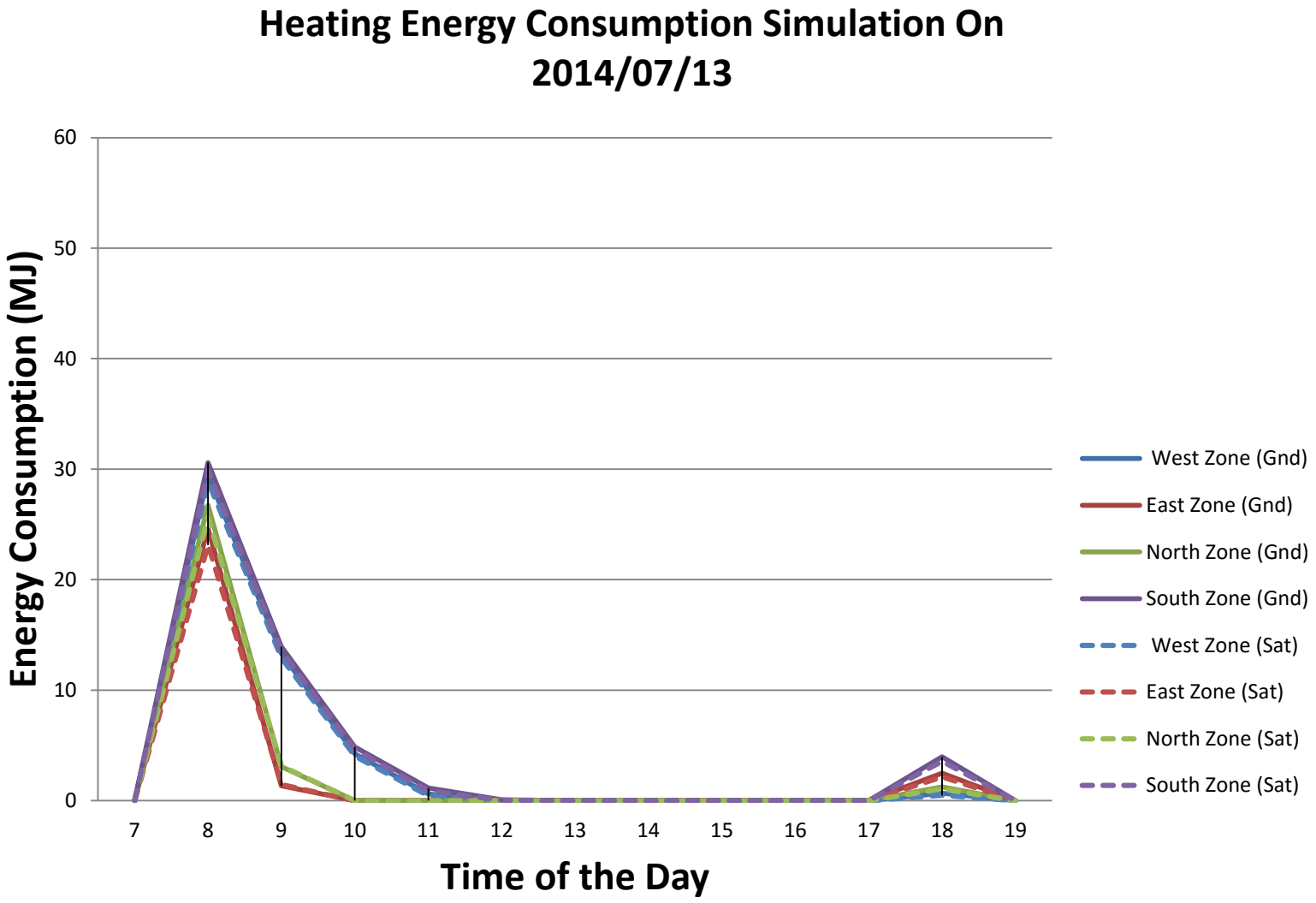
- With Ground Station Data

	Heat Energy Consumption			
	West	North	East	South
Max (MJ/hr)	29.4 (8AM, 13 Jul) High Error	26.8 (8AM, 24 Jul)	25.8 (8AM, 21 Jul)	30.6 (8AM, 13 Jul) High Error
Average (MJ/hr)	6.1	5.8	5.2	5.8
Std Dev (MJ/hr)	7.4	7.2	6.8	7.3

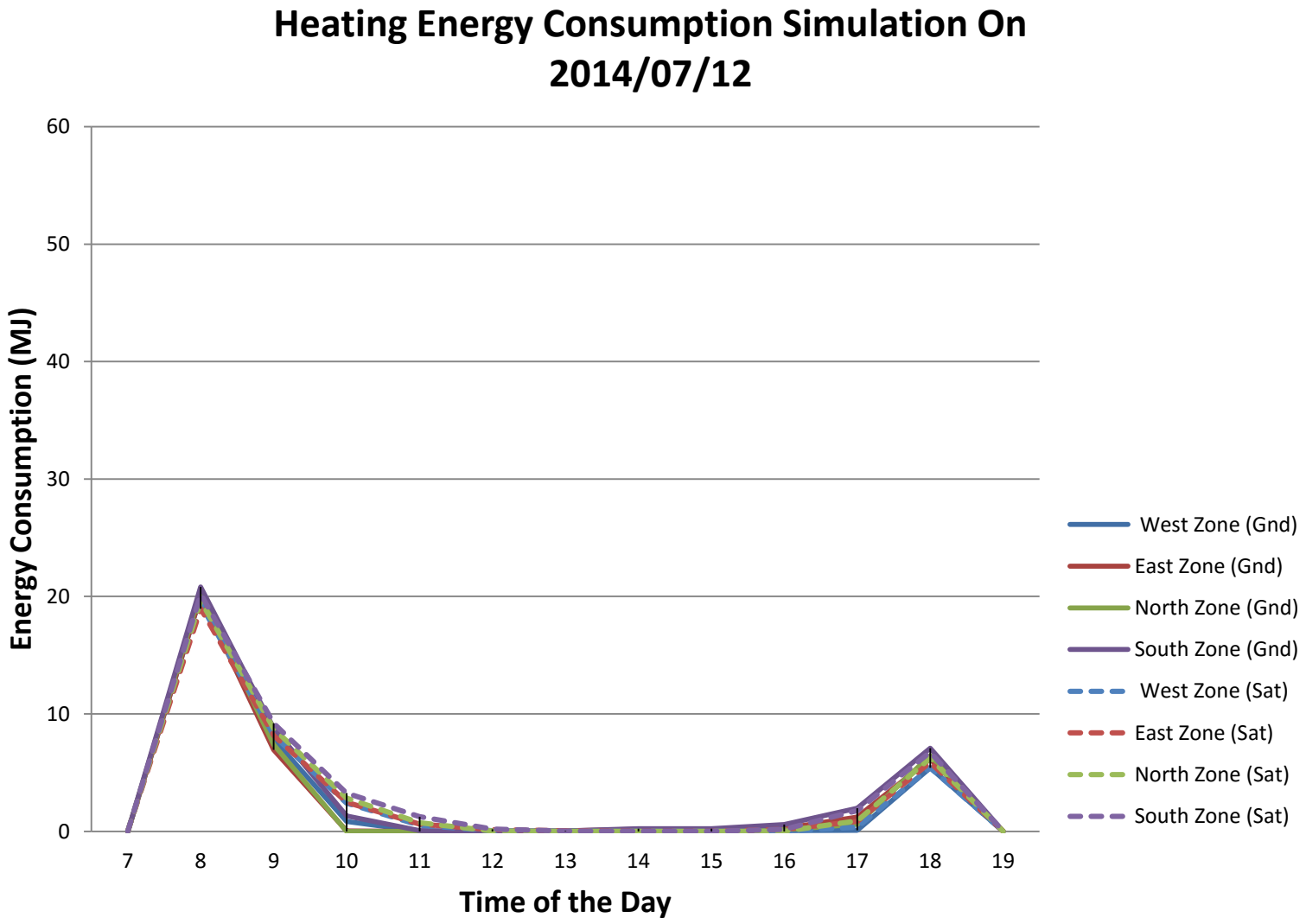
- With Satellite Data

	Heat Energy Consumption			
	West	North	East	South
Max (MJ/hr)	28.8 (8AM, 13 Jul) High Error	25.6 (8AM, 09 Aug)	24.6 (8AM, 09 Aug)	29.8 (8AM, 13 Jul) High Error
Average (MJ/hr)	6.1	5.4	4.6	5.8
Std Dev (MJ/hr)	7.2	6.9	6.3	7.2

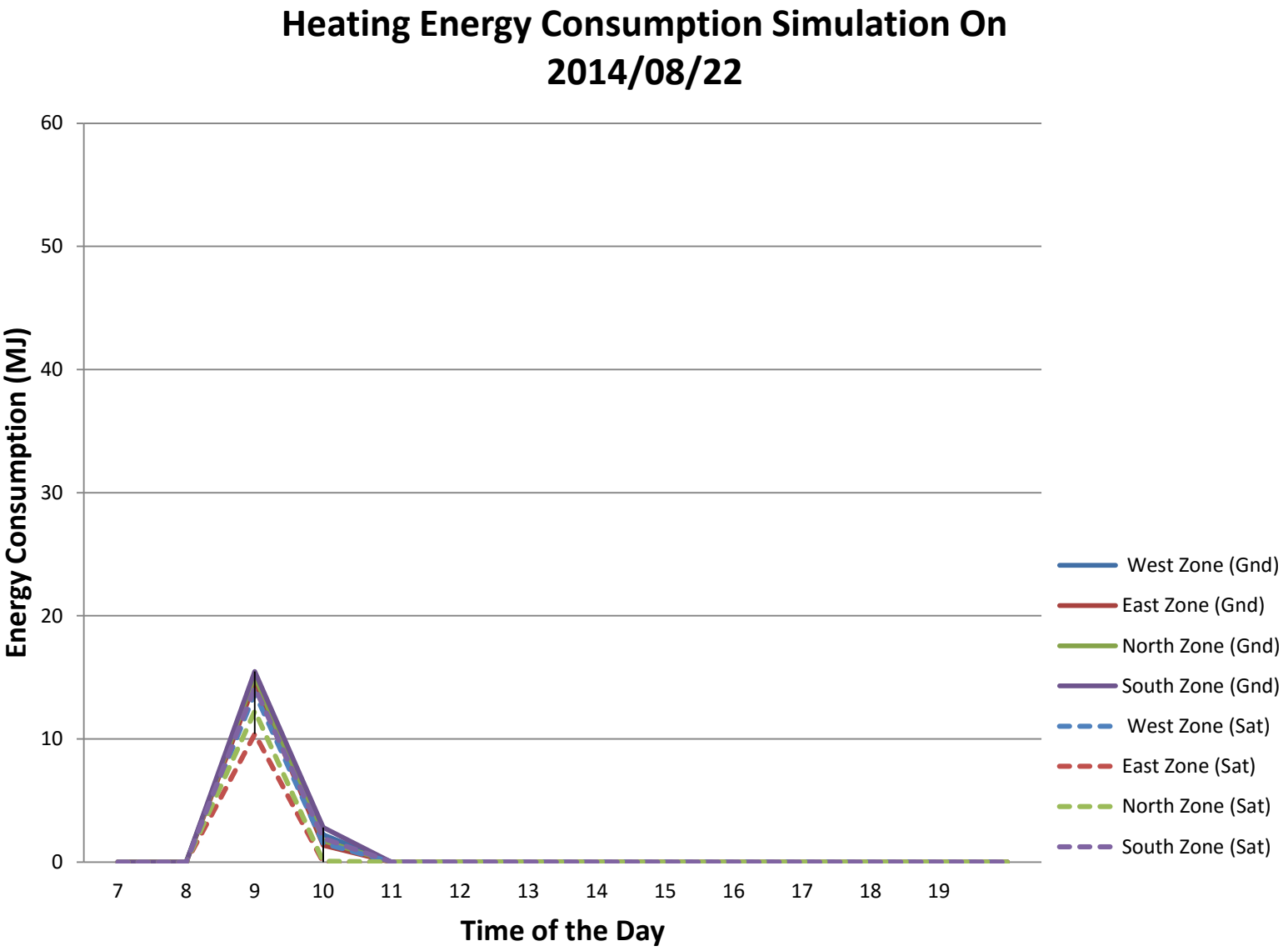
Heating Energy Consumption



Heating Energy Consumption



Heating Energy Consumption



Cooling Energy Consumption 2014

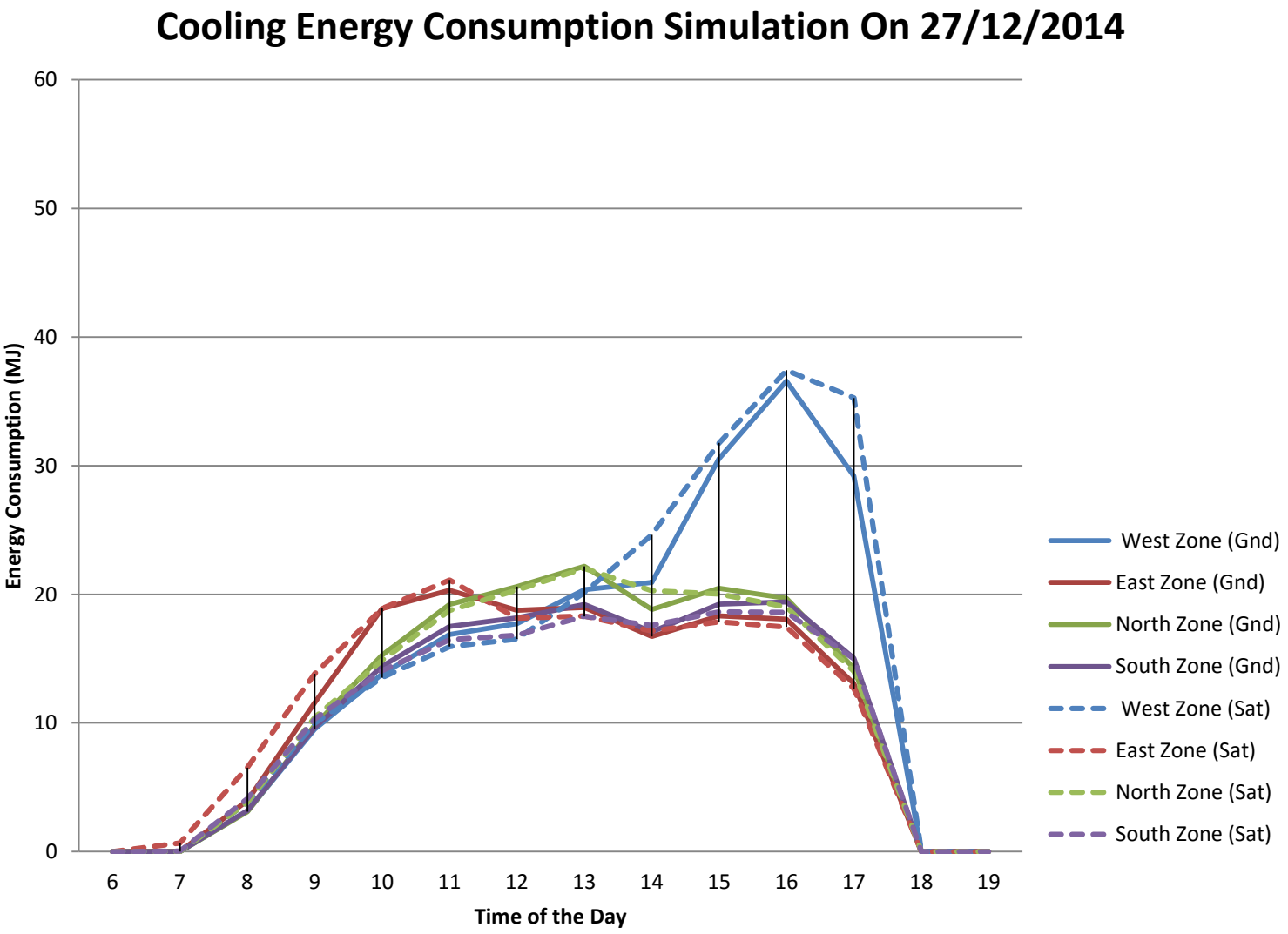
- With Ground Station Data

	Heat Energy Consumption			
	West	North	East	South
Max (MJ/hr)	59.5 (4PM, 02 Feb) High Error	42.2 (3PM, 02 Feb) High Error	48.4 (9AM, 02 Feb) High Error	37.4 (3PM, 02 Feb) High Error
Average (MJ/hr)	15.7	16.1	14.9	12.4
Std Dev (MJ/hr)	11.8	9.5	10.4	8.3

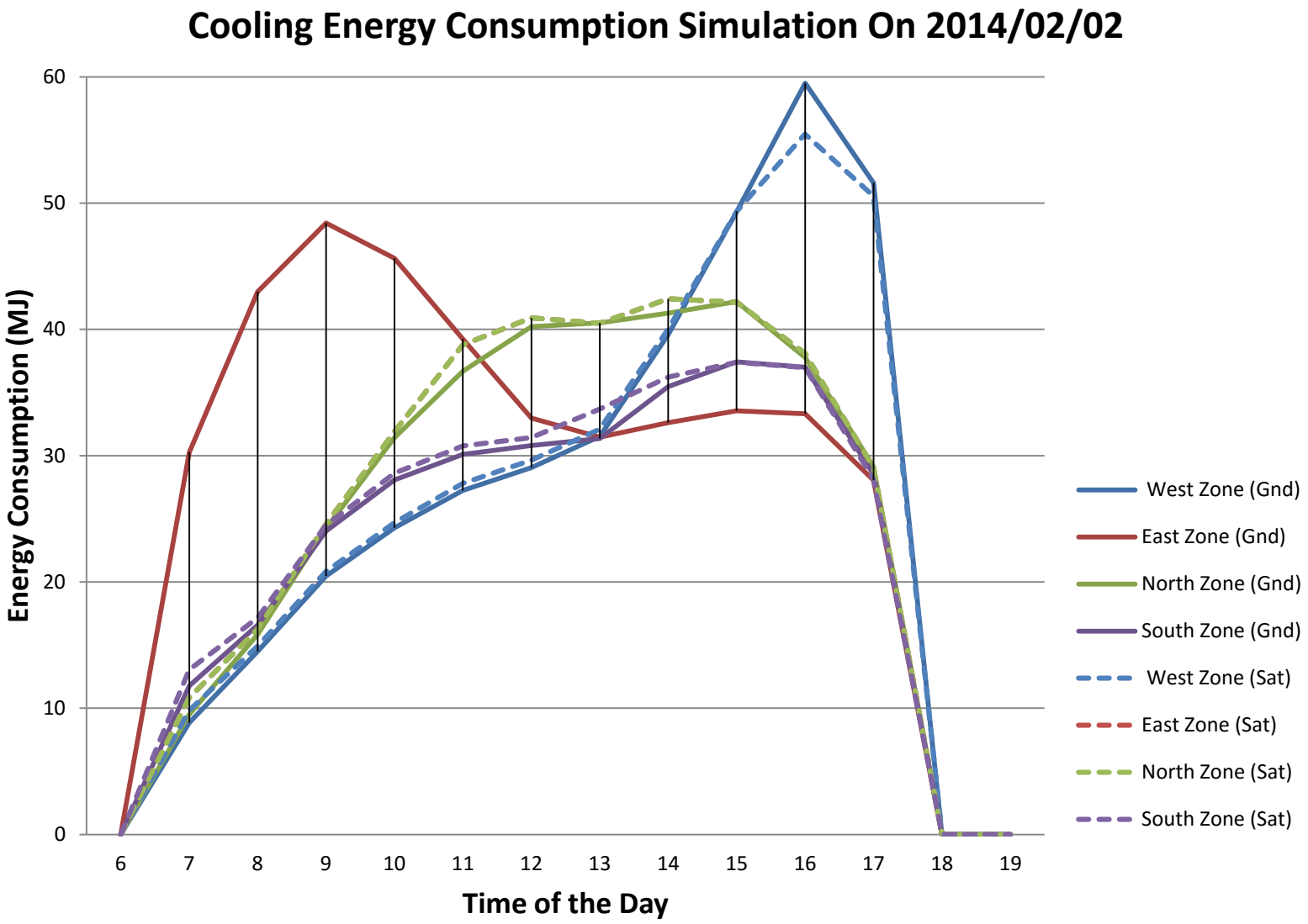
- With Satellite Data

	Cooling Energy Consumption			
	West	North	East	South
Max (MJ/hr)	60.1 (5PM, 07 Jan)	42.4 (2PM, 02 Feb) High Error	48.5 (9AM, 02 Feb) High Error	37.4 (3PM, 02 Feb) High Error
Average (MJ/hr)	15.8	16.2	15	12.5
Std Dev (MJ/hr)	11.9	9.6	10.4	8.4

Cooling Energy Consumption



Cooling Energy Consumption



Conclusions

Satellite estimated solar data can be improved by:

- Applying cloud height estimates to locate the cloud above the piece of ground that it is actually above; and
- Applying cloud height estimates with solar geometry to establish where the cloud's shadow actually falls.

But building simulations indicate that when the improved data is applied in industry and commerce it makes little difference to the estimated peak loads and annual energy consumption calculations.

This should now be checked for the more sensitive day-lit, passive solar and PV augmented buildings.

References

- 2013, Solar Energy Journal - C. Blanksby, D. Bennett, S. Langford, *Improvement to an existing satellite data set in support of an Australia solar atlas,* Melbourne, Victoria, Australia.
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- 2014, presentation Sydney – R. Davy et al, *Improving the accuracy of satellite irradiance estimates for Australia by combining with downscaled reanalysis*, CSIRO Canberra Available at http://???????
- 2015, updated presentation Boulder
  Available at http://icem2015.org/wp-content/uploads/2015/07/1330_RobertDavy.pdf
- 2014, presentation Sydney – G. Edwards and T. Lee, *Real time solar and coincident weather data for solar deployment and building optimisation and energy management*,
  Available at https://wiki.csiro.au/display/SRAF/Solar+Resource+Assessment+and+Forecasting+Home
- 2015, updated presentation Canberra - Alternative Technology Association, Canberra ACT Australia
  Available at http://community.ata.org.au/wp-content/uploads/2015/06/Real-Time-Weather-Data-Applications.pdf

Acknowledgements

Dr Ian Grant (Satellite Specialist) and Ian Muirhead (Climate & Oceans Data & Analysis Services) both of the Australian Bureau of Meteorology, have assisted with the progress of this work and with critiquing this presentation in draft form.

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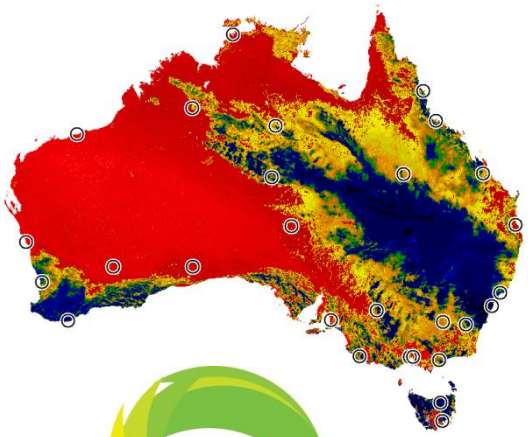

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Questions?

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