Inspection and compliance checks for Solar PV Systems (AS/NZS / NEC)

Session 1B: Solar Resources

The Solar Resource

- The electrical output of a PV module is proportional to the amount of solar irradiation incident on its surface. (Note: Solar power is Irradiance (W/m^2) and Solar energy is irradiation (kWh/m^2).

- Hence for the system designer it is important to determine the amount of solar irradiation that is incident on the PV module throughout the day and this then allows them to determine the energy yield of the grid connected PV system. Solar irradiation varies for different sites depending on their location (especially latitude), time and day of the year, weather and also on the orientation of the PV module.

- Example - The maps and data for Papua New Guinea

https://solargis.com/maps-and-gis-data/download/papua-new-guinea

Irradiance

- The amount of solar power available per unit area is known as the irradiance (symbol = G).
- The measuring devices for irradiance are pyranometers or reference solar cells.

Units	kW/m^2, W/m^2 or mW/cm^2
Peak Value	1000 W/m^2
Nominal Value	800 W/m^2

Note: In tropics higher values can be obtained.

Irradiation and Peak Sun Hours

- Irradiation is the total quantity of radiant solar energy per unit area received over a given period.

  - Remember: Energy = Power x Time

- Daily irradiation is commonly called: daily Peak Sun Hours (PSH).
- The number of peak sun hours (PSH) for the day is the number of hours for which energy at the rate of 1kW/m^2 would give an equivalent amount of energy to the total energy for that day.

Irradiation and Peak Sun Hours

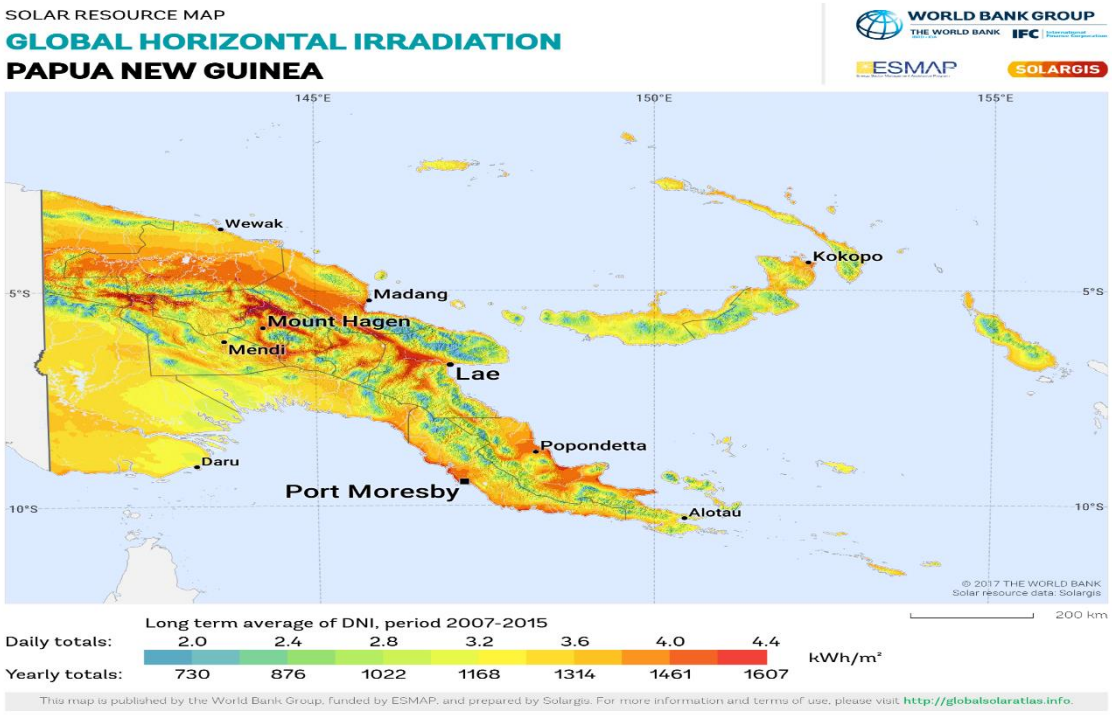
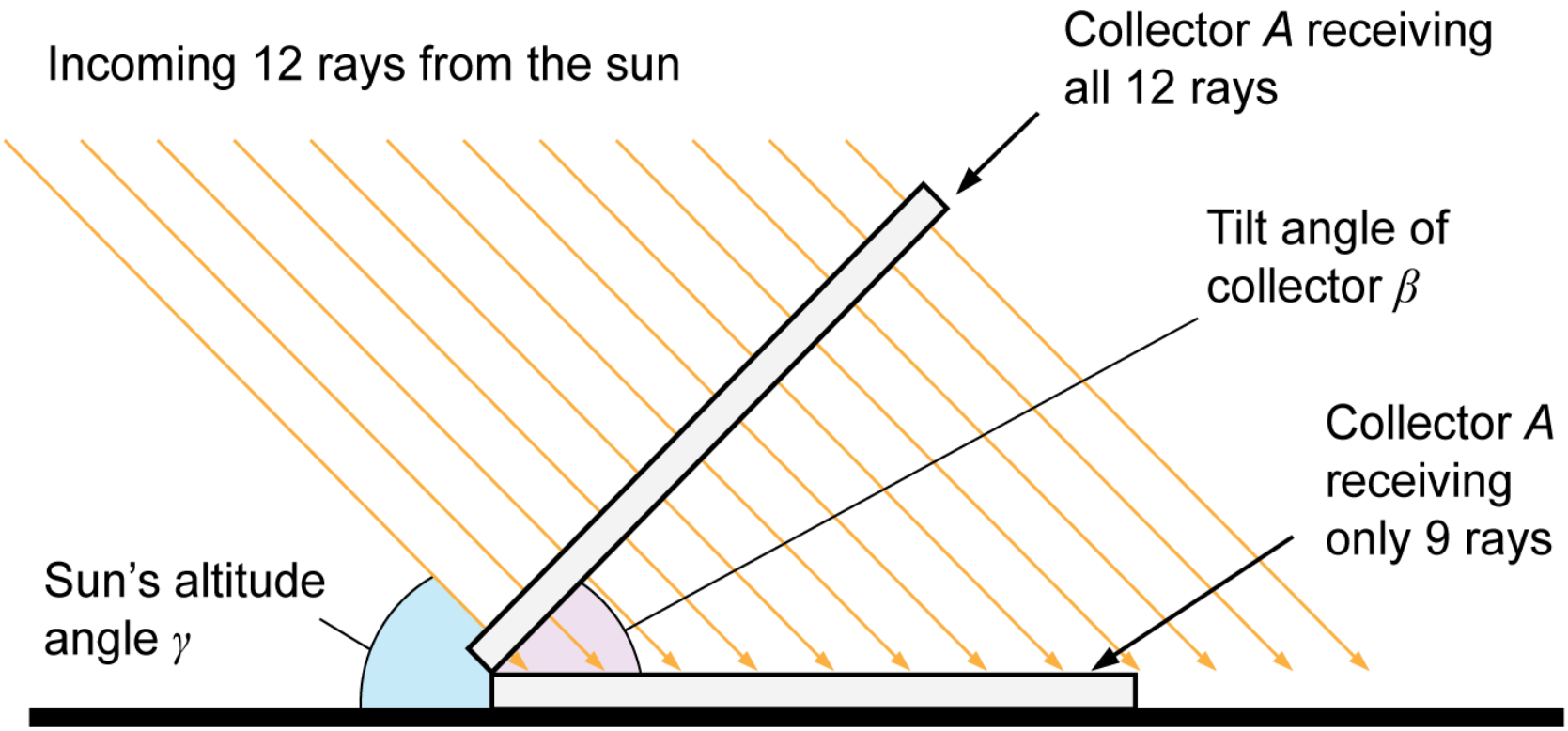


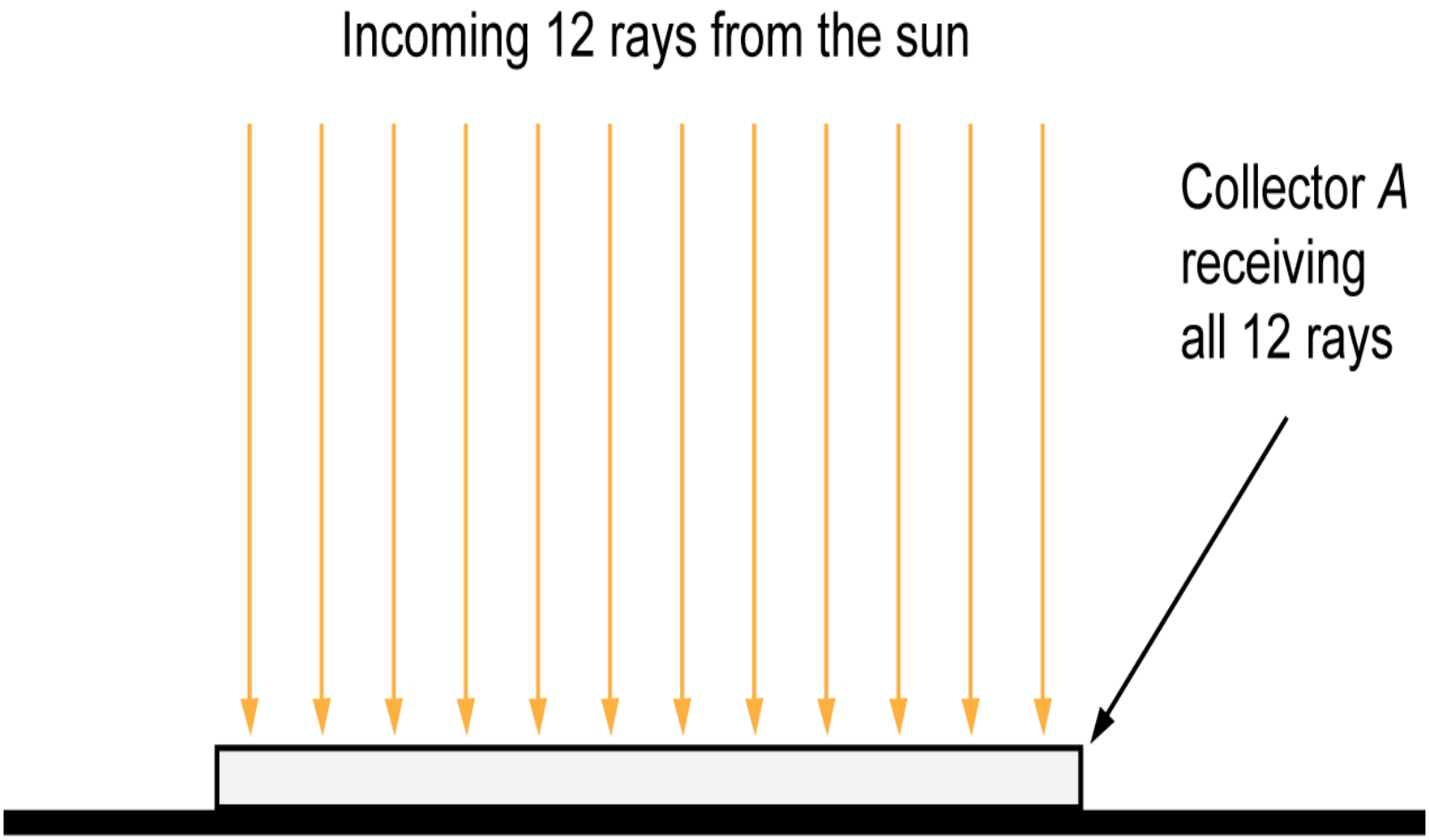
Figure 3: PNG Global Horizontal Irradiation

© 2020 The World Bank, Source: Global Solar Atlas 2.0, Solar resource data: Solargis.

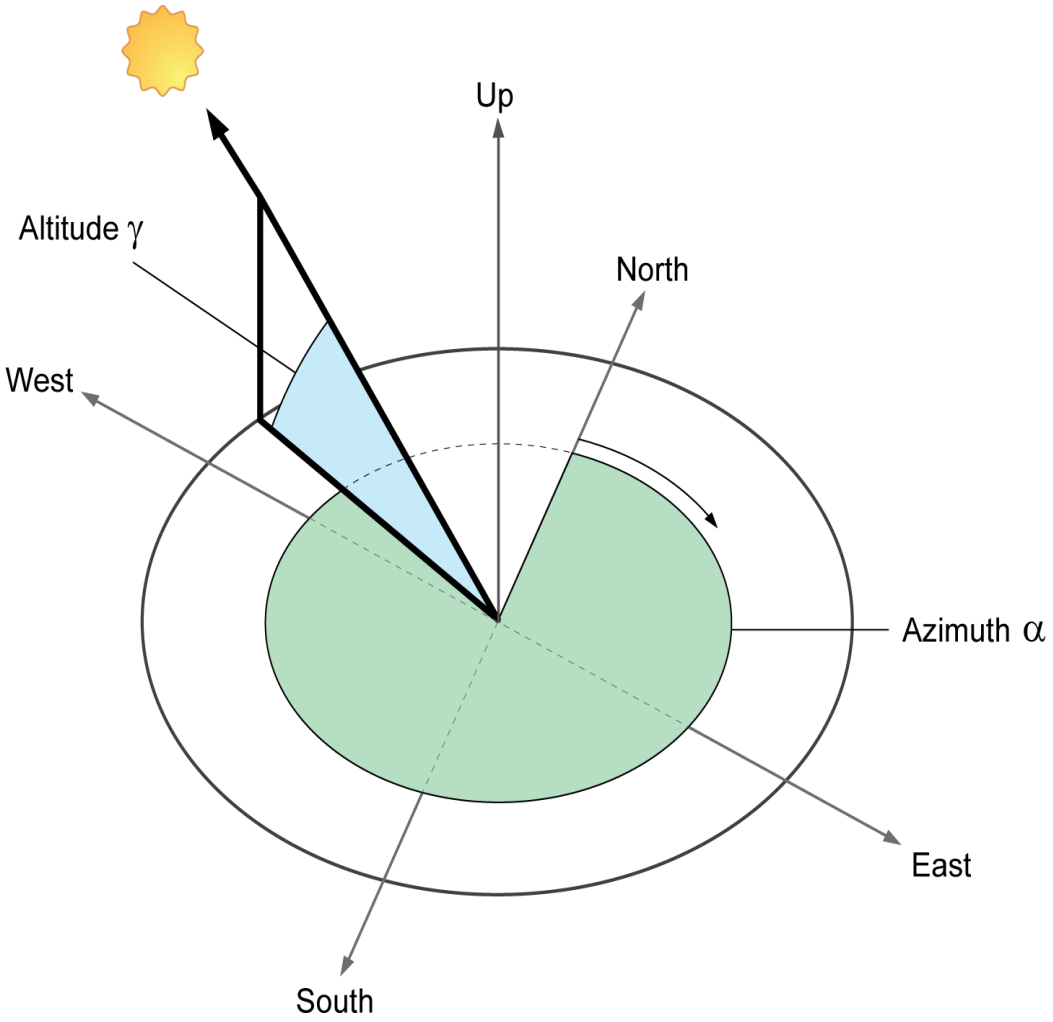
Geometric Effects



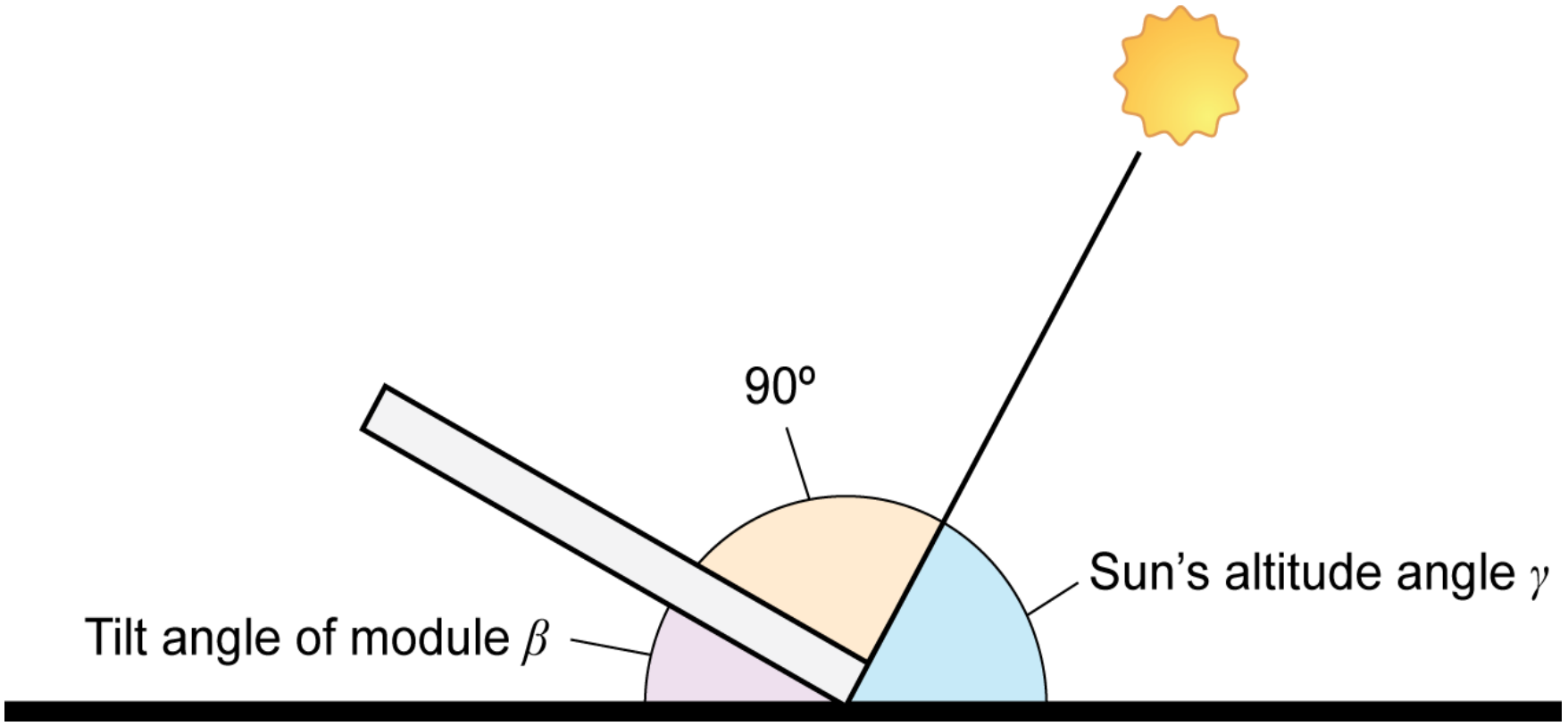
Geometric Effects



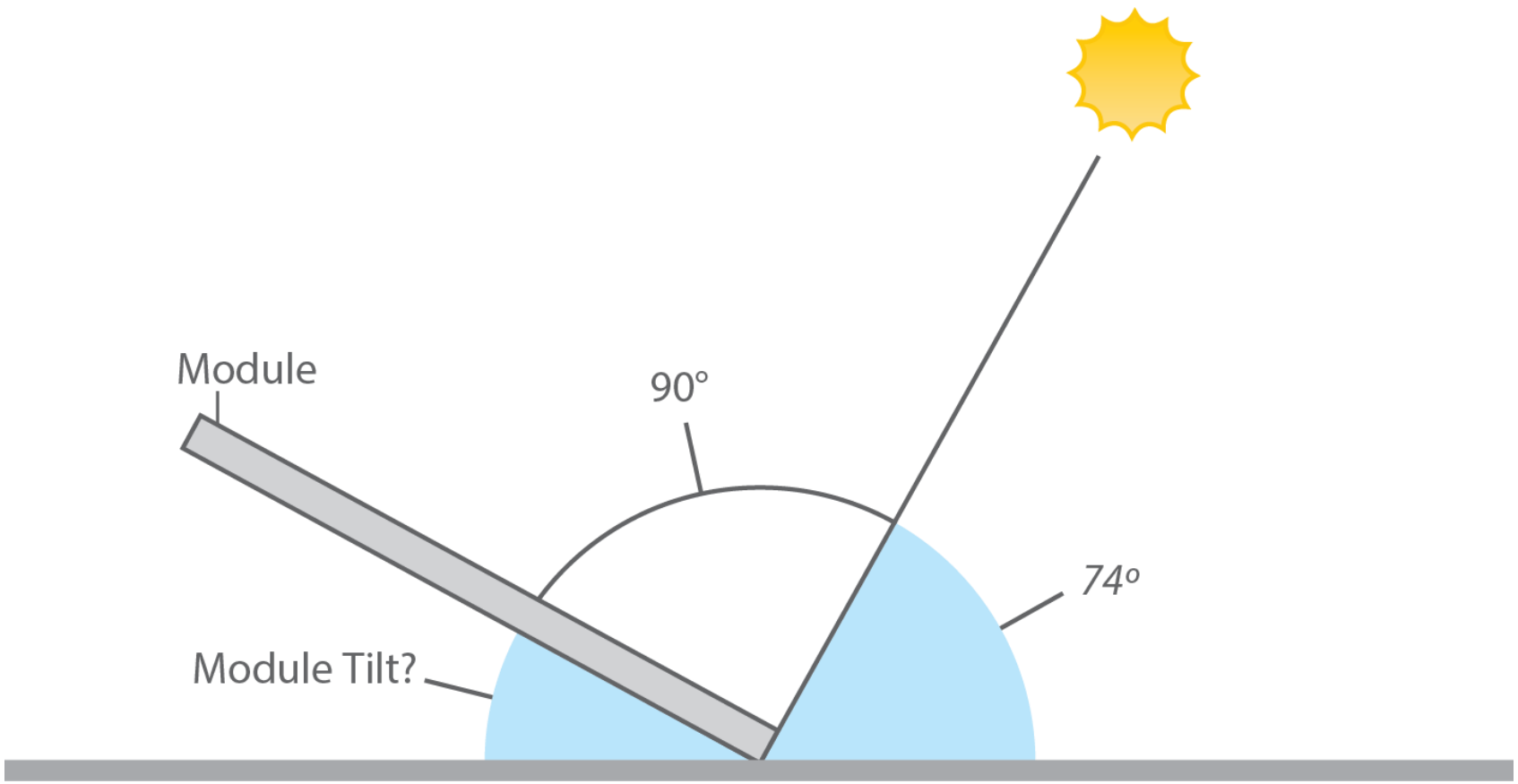
Altitude and Azimuth



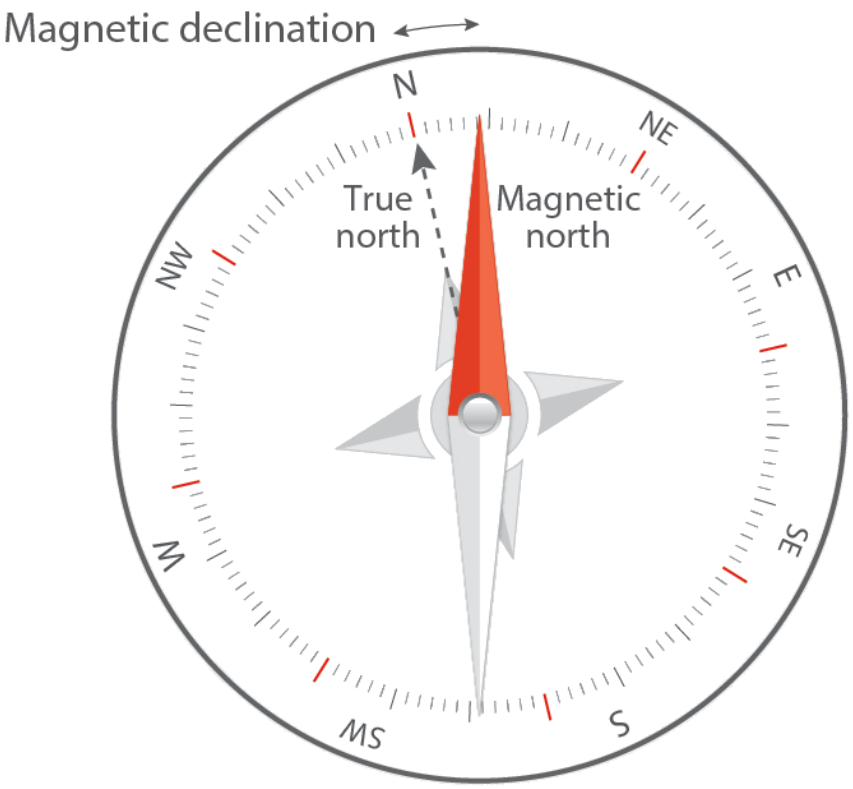
Solar Module in Relation to Sun's Altitude



Solar Module In Relation to Sun's Altitude



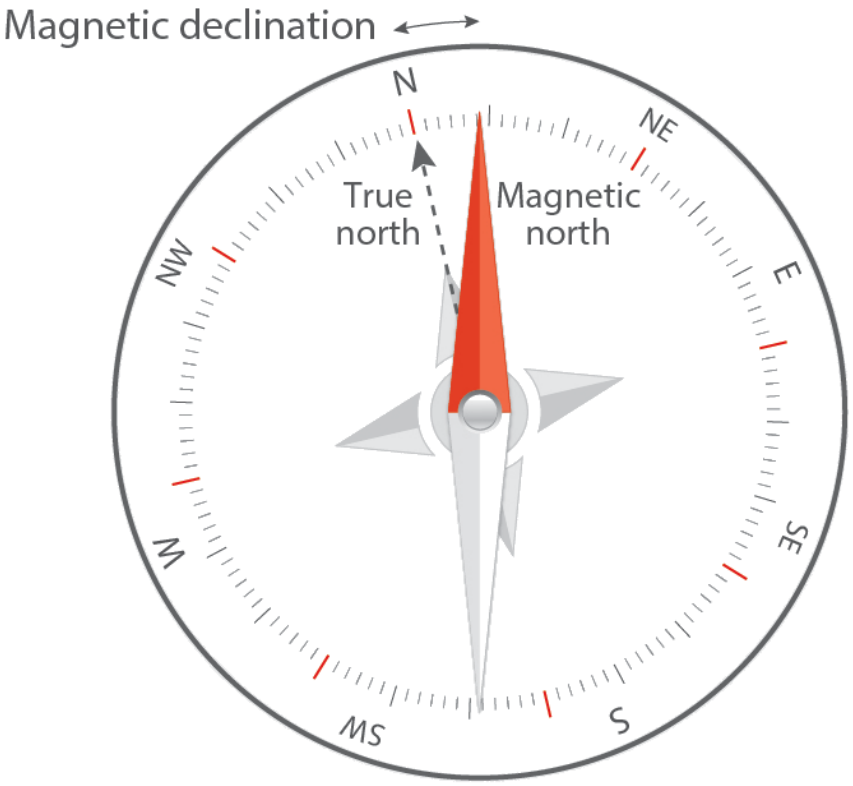
Magnetic North and True North



In Suva, Fiji:

- The magnetic deviation is 12° 35’ East.
- This means that True North is approximately 12° 35’ West of magnetic North.
- Always check site specific magnetic deviation – varies between islands
- You may use a resource such as http://www.magnetic-declination.com/

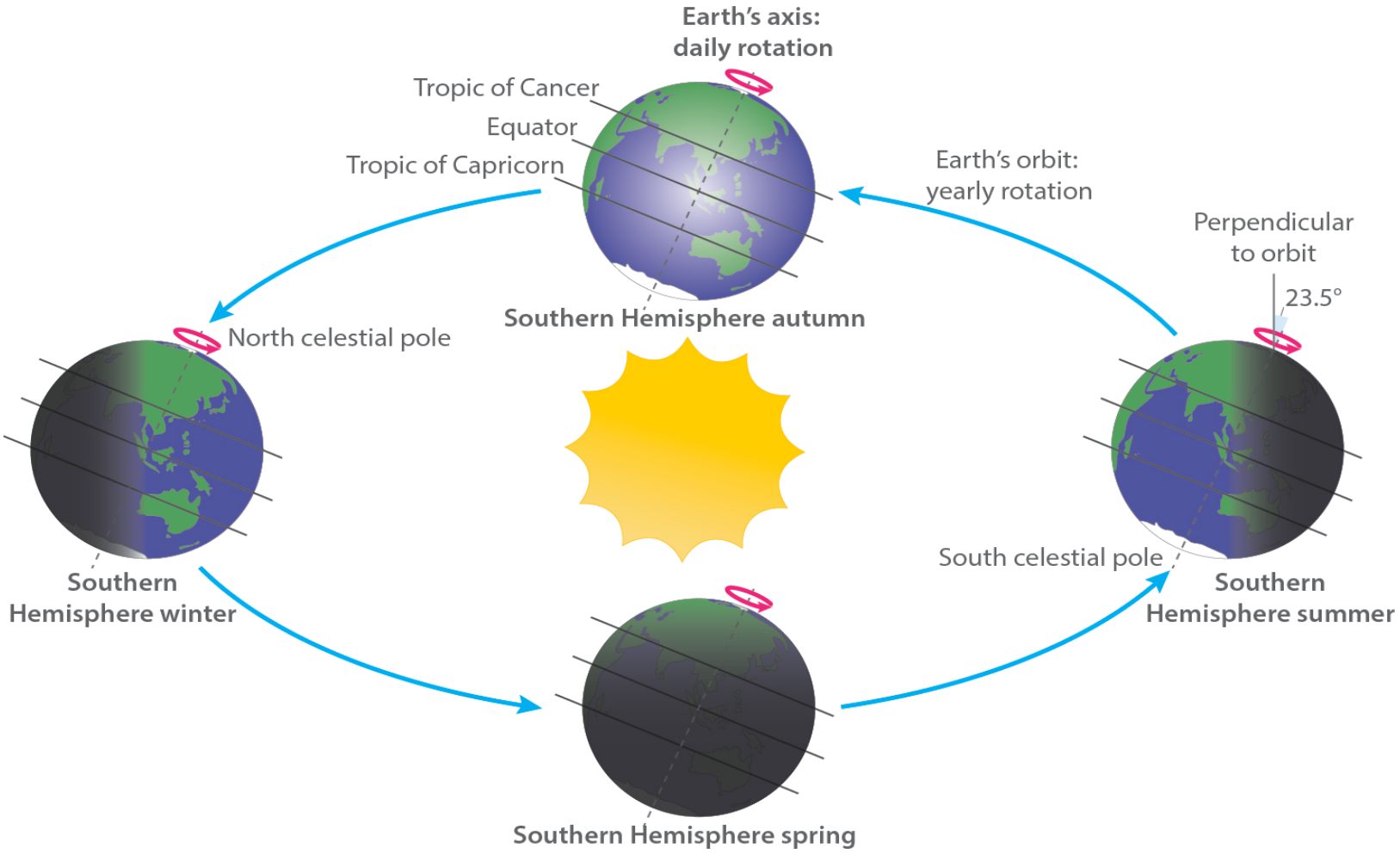
Magnetic North and True North



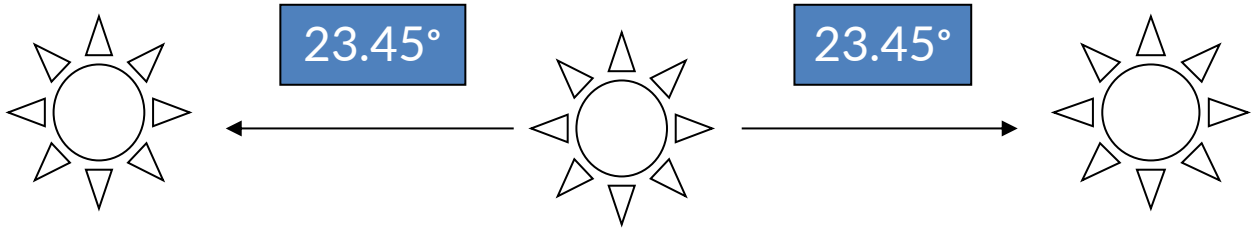
In Pohnpei:

- The magnetic deviation is 5.71° East.
- This means that True North is approximately 5.71° West of magnetic North.
- Always check site specific magnetic deviation – varies between islands
- You may use a resource such as http://www.magnetic-declination.com/

Variation of Sun Through The Year



Variation of Sun Through The Year



Solstice
Approximately
December 22nd

Equinox
Approximately March
21st and September 23rd

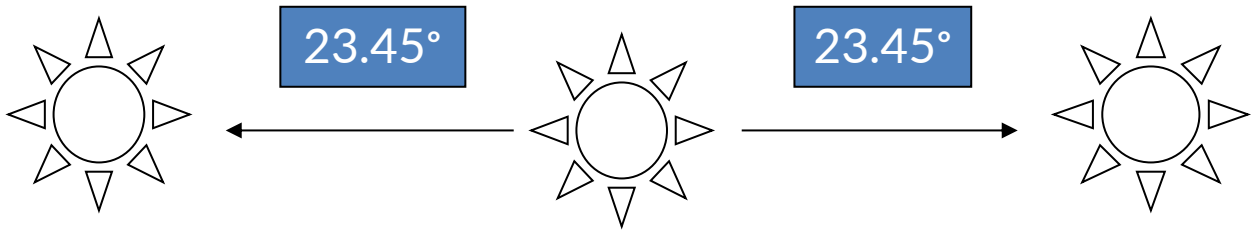
Solstice
Approximately
June 21st

December Solstice Sun over tropic of Capricorn	Equinox Sun over the Equator	June Solstice Sun over tropic of Cancer

The altitude of the sun at Solar Noon will vary 46.9 degrees between the December solstice and June solstice.

The actual altitude will depend on the latitude of the location

Variation of Sun Through The Year



Solstice
Approximately
December 22nd

Equinox
Approximately March
21st and September 23rd

Solstice
Approximately
June 21st

The altitude at the equinox = 90° - Latitude Angle

The altitude at the solstices = 90° - Latitude angle ± 23.45°

The sun (at the solstice) is in same hemisphere as the location
Altitude = 90° - Latitude Angle + 23.45°

The sun (at the solstice) is in opposite hemisphere to the location
Altitude = 90° - Latitude Angle - 23.45°

Variation of Sun (at Noon) Through the Year in Suva, Fiji (18.1°S)

Altitude looking North is:

- Equinox: 90 – latitude

  = 90 – 18.1 = 71.9°

- June Solstice: 90 – latitude - 23.45

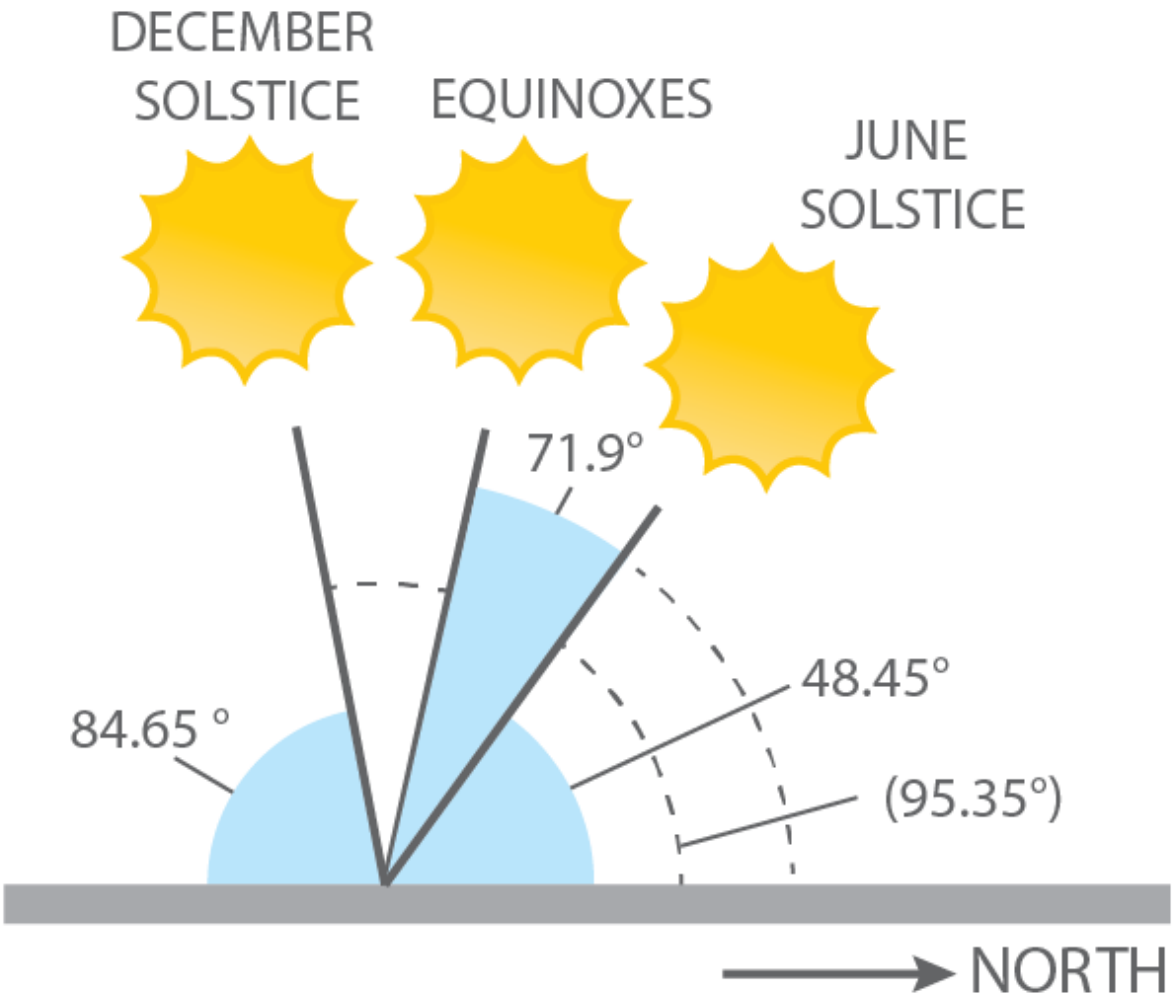
  = 90 – 18.1 - 23.45 = 48.45°

- December Solstice: 90 – latitude + 23.45

  = 90 – 18.1 + 23.45 = 95.35°

Thus Alts = 180 - 95.35 = 84.65° looking south

Variation of Sun Through the Year in Suva



Variation of Sun (at Noon) Through the Year in Pohnpei (6.85°N)

Altitude looking towards the equator

- Equinox: 90 – latitude

  = 90 – 6.85 = 83.15°

- June Solstice: 90 – latitude + 23.45

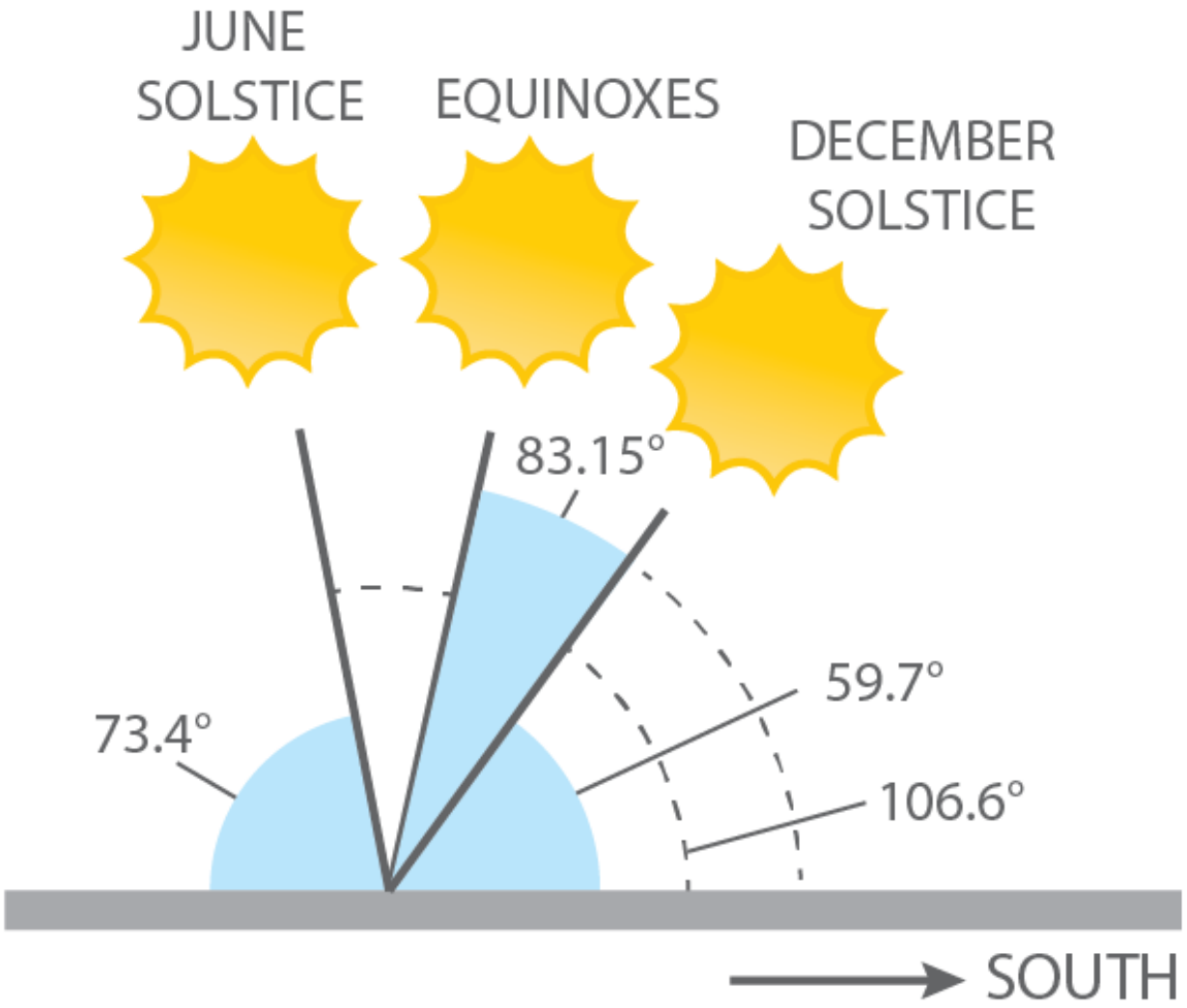
  = 90 – 6.85 + 23.45 = 106.6°

  Thus Alts = 180 – 106.6 = 73.4° looking North

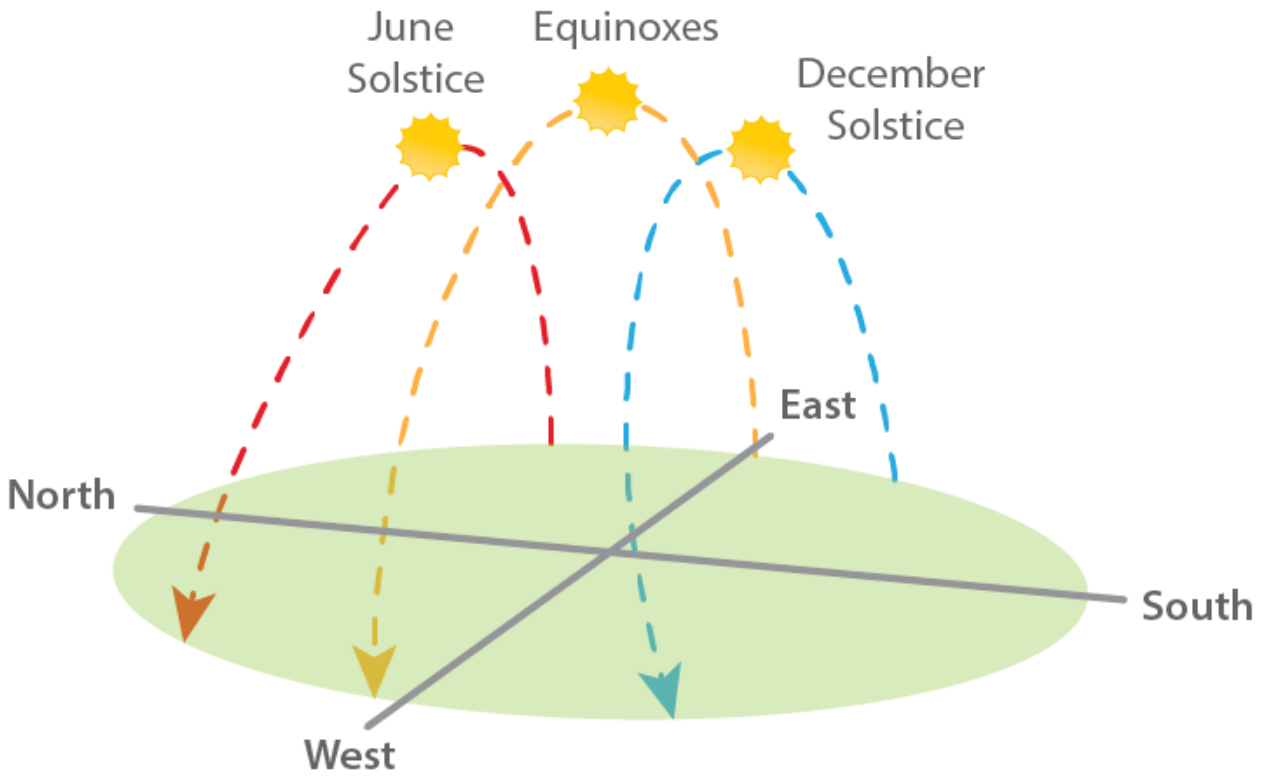
- December Solstice: 90 – latitude - 23.45

  = 90 – 6.85 - 23.45 = 59.7°

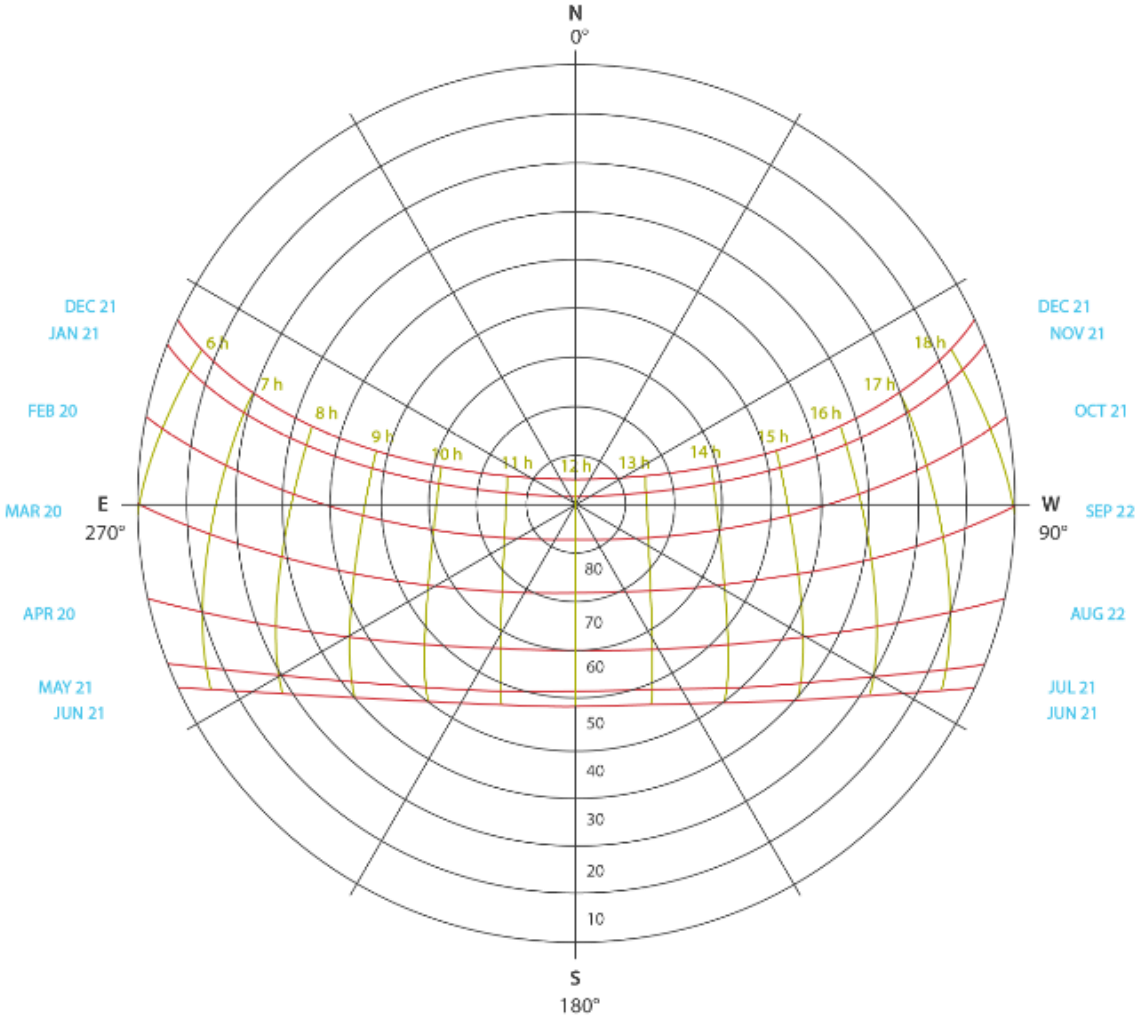
Variation of Sun Through the Year in Pohnpei



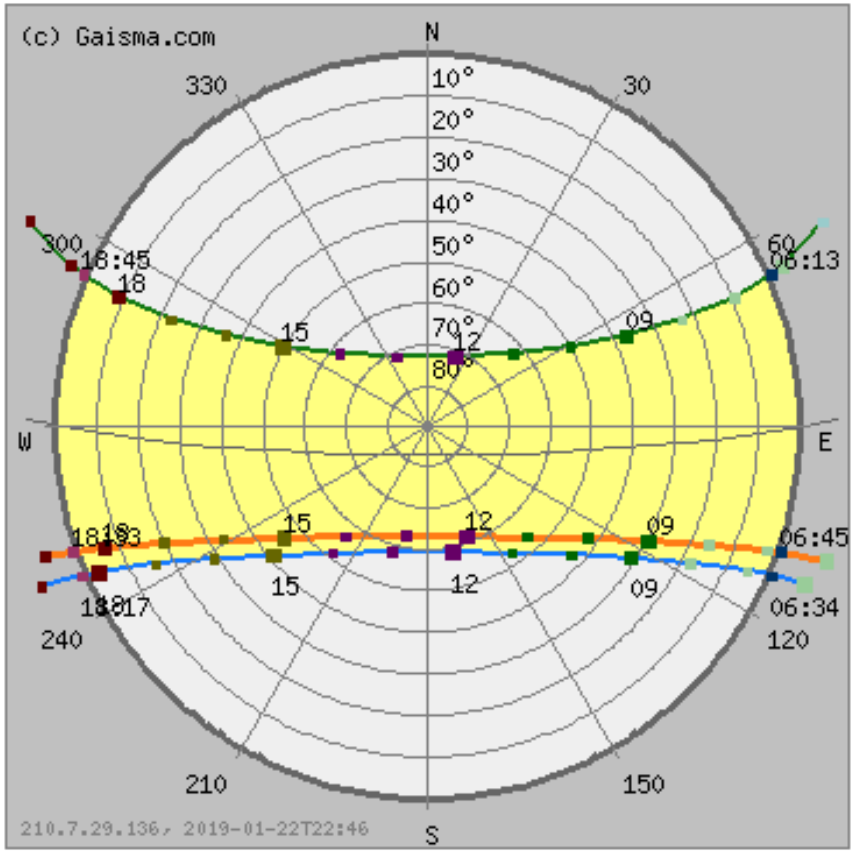
Representing the Sunpath During the Year



Sunpath Diagram for Fiji (18.1°S)



Sunpath Diagram for Pohnpei (6.85°N)



Sun path

- Today
- June solstice
- December solstice
- Annual variation
- Equinox (March and September)

Sunrise/sunset

- Sunrise
- Sunset

Time

- 00-02
- 03-05
- 06-08
- 09-11
- 12-14
- 15-17
- 18-20
- 21-23

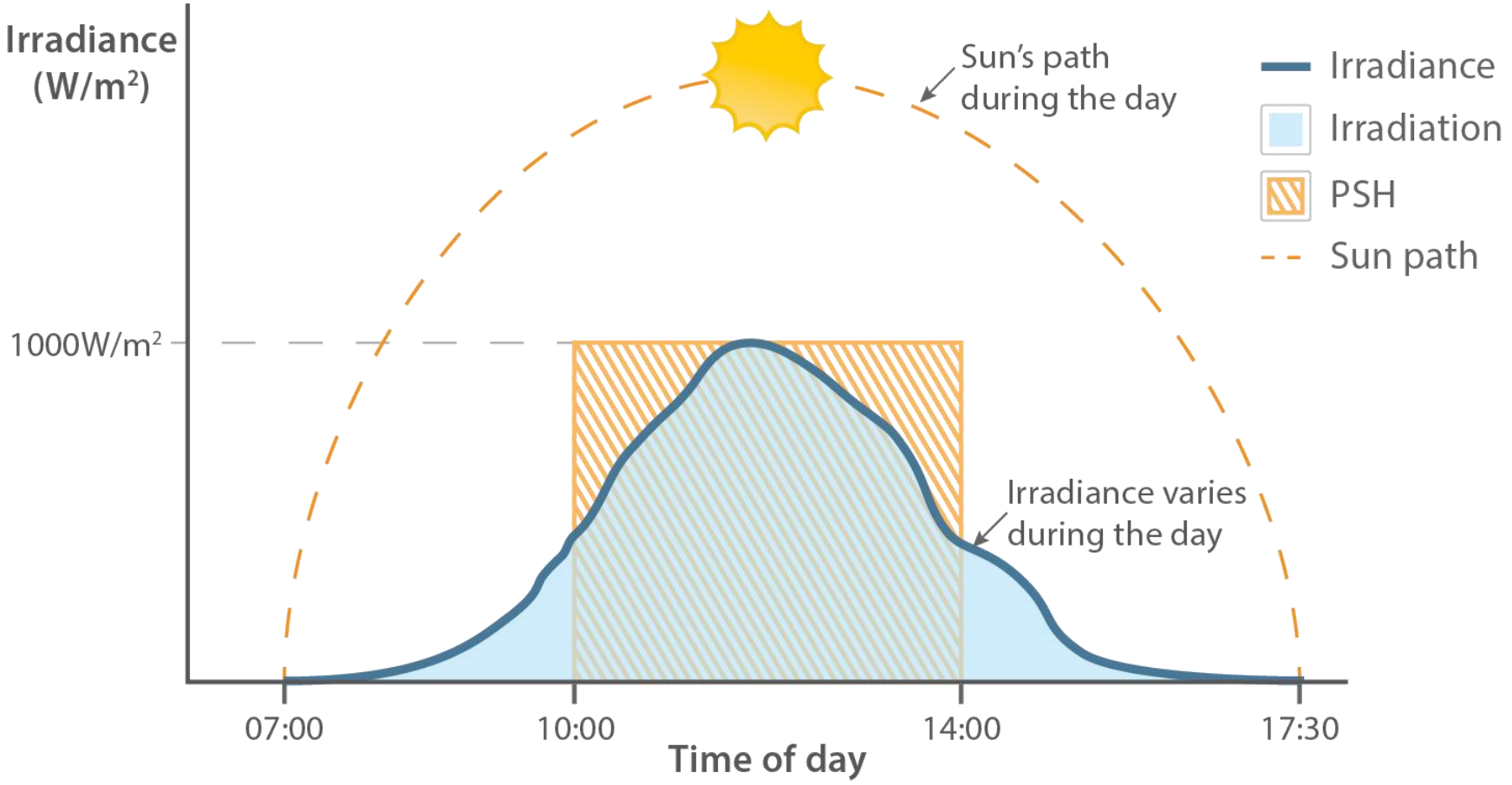
Irradiation and Peak Sun Hours

- Irradiation is the total quantity of radiant solar energy per unit area received over a given period.

  - Remember: Energy = Power x Time

- Daily irradiation is commonly called: daily Peak Sun Hours (PSH).
- The number of peak sun hours (PSH) for the day is the number of hours for which energy at the rate of 1kW/m^2 would give an equivalent amount of energy to the total energy for that day.

Peak Sun Hours



Measurement of Peak Sun Hours

- Can look up PSH on a plane surface, at any tilt, for any location using Latitude and Longitude.
- E.g. Fiji: 18.1°S, 178.42°E

https://power.larc.nasa.gov/data-access-viewer/

MONTH	Suva 18.1°S	
	0° Tilt (flat)	18° Tilt
January	6.26	6.25
February	5.82	5.61
March	5.46	5.53
April	4.63	4.99
May	4.02	4.60
June	3.69	4.37
July	3.87	4.51
August	4.39	4.86
September	5.03	5.21
October	5.95	5.83
November	6.14	6.04
December	6.38	6.42
Average PSH	5.14	5.35

Effect on irradiation due to orientation and tilt angle.

ANNUAL DAILY IRRADIATION ON AN INCLINED PLANE EXPRESSED AS % OF MAXIMUM VALUE FOR SUVA - FIJI
Latitude: 18 degrees 08 minutes South
Longitude: 178 degrees 25 minutes East

Plane Azimuth (degrees)	Plane Inclination (degrees)									
	0	10	20	30	40	50	60	70	80	90
0	97%	100%	100%	98%	95%	90%	83%	76%	67%	54%
10	97%	100%	100%	98%	95%	90%	83%	75%	67%	54%
20	97%	99%	100%	98%	94%	89%	82%	74%	66%	53%
30	97%	99%	99%	97%	93%	88%	81%	73%	64%	51%
40	97%	99%	98%	96%	92%	86%	79%	71%	62%	49%
50	97%	98%	98%	95%	91%	84%	77%	68%	59%	47%
60	97%	98%	97%	94%	89%	82%	74%	65%	56%	44%
70	97%	97%	96%	92%	87%	80%	71%	62%	52%	41%
80	97%	97%	95%	90%	84%	77%	68%	59%	48%	38%
90	97%	96%	93%	89%	82%	74%	65%	55%	44%	35%
100	97%	96%	92%	87%	80%	72%	62%	51%	41%	32%
110	97%	95%	91%	85%	78%	69%	59%	48%	37%	28%
120	97%	95%	90%	84%	76%	66%	56%	45%	33%	26%
130	97%	94%	89%	82%	74%	64%	53%	42%	30%	25%
140	97%	94%	88%	81%	72%	62%	51%	39%	29%	24%
150	97%	94%	88%	80%	71%	61%	49%	38%	28%	24%
160	97%	93%	87%	79%	70%	59%	48%	37%	27%	24%
170	97%	93%	87%	79%	69%	59%	47%	36%	27%	24%
180	97%	93%	87%	79%	69%	58%	47%	36%	27%	24%
190	97%	93%	87%	79%	69%	59%	47%	36%	27%	24%
200	97%	93%	87%	79%	70%	59%	48%	37%	27%	24%
210	97%	94%	88%	80%	71%	61%	49%	38%	28%	24%
220	97%	94%	88%	81%	72%	62%	51%	39%	29%	24%
230	97%	94%	89%	82%	74%	64%	53%	42%	30%	25%
240	97%	95%	90%	84%	76%	66%	56%	45%	33%	26%
250	97%	95%	91%	85%	78%	69%	59%	48%	37%	28%
260	97%	96%	92%	87%	80%	72%	62%	51%	41%	32%
270	97%	96%	93%	89%	82%	74%	65%	55%	44%	35%
280	97%	97%	95%	90%	84%	77%	68%	59%	48%	38%
290	97%	97%	96%	92%	87%	80%	71%	62%	52%	41%
300	97%	98%	97%	94%	89%	82%	74%	65%	56%	44%
310	97%	98%	98%	95%	91%	84%	77%	68%	59%	47%
320	97%	99%	98%	96%	92%	86%	79%	71%	62%	49%
330	97%	99%	99%	97%	93%	88%	81%	73%	64%	51%
340	97%	99%	100%	98%	94%	89%	82%	74%	66%	53%
350	97%	100%	100%	98%	95%	90%	83%	75%	67%	54%

Measurement of Peak Sun Hours

- Can look up PSH on a plane surface, at any tilt, for any location using Latitude and Longitude.
- E.g. Pohnpei: 6.85°N, 158.26°E

https://power.larc.nasa.gov/data-access-viewer/

MONTH	Pohnpei 6.85°N	
	0° Tilt (flat)	6° Tilt
January	4.92	5.12
February	5.27	5.40
March	5.84	5.88
April	5.71	5.71
May	5.35	5.41
June	5.24	5.33
July	5.43	5.52
August	5.47	5.50
September	5.56	5.56
October	5.24	5.33
November	4.99	5.17
December	4.78	5.00
Average PSH	5.32	5.41

Effect on irradiation due to orientation and tilt angle.

ANNUAL DAILY IRRADIATION ON AN INCLINED PLANE EXPRESSED AS % OF MAXIMUM VALUE FOR PALIKIR – POHNPEI FSM
Latitude: 6 degrees 54 minutes North
Longitude: 158 degrees 13 minutes East

Plane Azimuth (degrees)	Plane Inclination (degrees)									
	0	10	20	30	40	50	60	70	80	90
0	99.8%	98%	94%	88%	81%	73%	64%	51%	41%	31%
10	99.8%	98%	94%	88%	81%	73%	64%	51%	41%	31%
20	99.8%	98%	94%	88%	81%	73%	64%	52%	41%	31%
30	99.8%	98%	94%	88%	82%	73%	64%	52%	41%	31%
40	99.8%	98%	94%	89%	82%	74%	64%	53%	42%	31%
50	99.8%	98%	94%	89%	82%	74%	64%	54%	43%	31%
60	99.8%	98%	95%	89%	83%	74%	64%	54%	43%	32%
70	99.8%	98%	95%	90%	83%	74%	65%	55%	44%	34%
80	99.8%	99%	95%	90%	83%	75%	65%	56%	46%	35%
90	99.8%	99%	96%	91%	84%	75%	65%	57%	47%	36%
100	99.8%	99%	96%	91%	84%	75%	65%	59%	48%	37%
110	99.8%	99%	97%	92%	85%	76%	66%	60%	49%	39%
120	99.8%	99%	97%	92%	85%	76%	66%	61%	50%	40%
130	99.8%	99.6%	97%	93%	86%	76%	66%	61%	51%	41%
140	99.8%	99.7%	97%	93%	86%	77%	66%	62%	52%	42%
150	99.8%	99.8%	98%	93%	86%	77%	66%	63%	53%	42%
160	99.8%	99.9%	98%	93%	87%	77%	66%	63%	53%	43%
170	99.8%	100%	98%	93%	87%	77%	67%	63%	53%	43%
180	99.8%	100%	98%	94%	87%	77%	67%	64%	53%	43%
190	99.8%	100%	98%	93%	87%	77%	67%	63%	53%	43%
200	99.8%	99.9%	98%	93%	87%	77%	66%	63%	53%	43%
210	99.8%	99.8%	98%	93%	86%	77%	66%	63%	53%	42%
220	99.8%	99.7%	97%	93%	86%	77%	66%	62%	52%	42%
230	99.8%	99.6%	97%	93%	86%	76%	66%	61%	51%	41%
240	99.8%	99%	97%	92%	85%	76%	66%	61%	50%	40%
250	99.8%	99%	97%	92%	85%	76%	66%	60%	49%	39%
260	99.8%	99%	96%	91%	84%	75%	65%	59%	48%	37%
270	99.8%	99%	96%	91%	84%	75%	65%	57%	47%	36%
280	99.8%	99%	95%	90%	83%	75%	65%	56%	46%	35%
290	99.8%	98%	95%	90%	83%	74%	65%	55%	44%	34%
300	99.8%	98%	95%	89%	83%	74%	64%	54%	43%	32%
310	99.8%	98%	94%	89%	82%	74%	64%	54%	43%	31%
320	99.8%	98%	94%	89%	82%	74%	64%	53%	42%	31%
330	99.8%	98%	94%	88%	82%	73%	64%	52%	41%	31%
340	99.8%	98%	94%	88%	81%	73%	64%	52%	41%	31%
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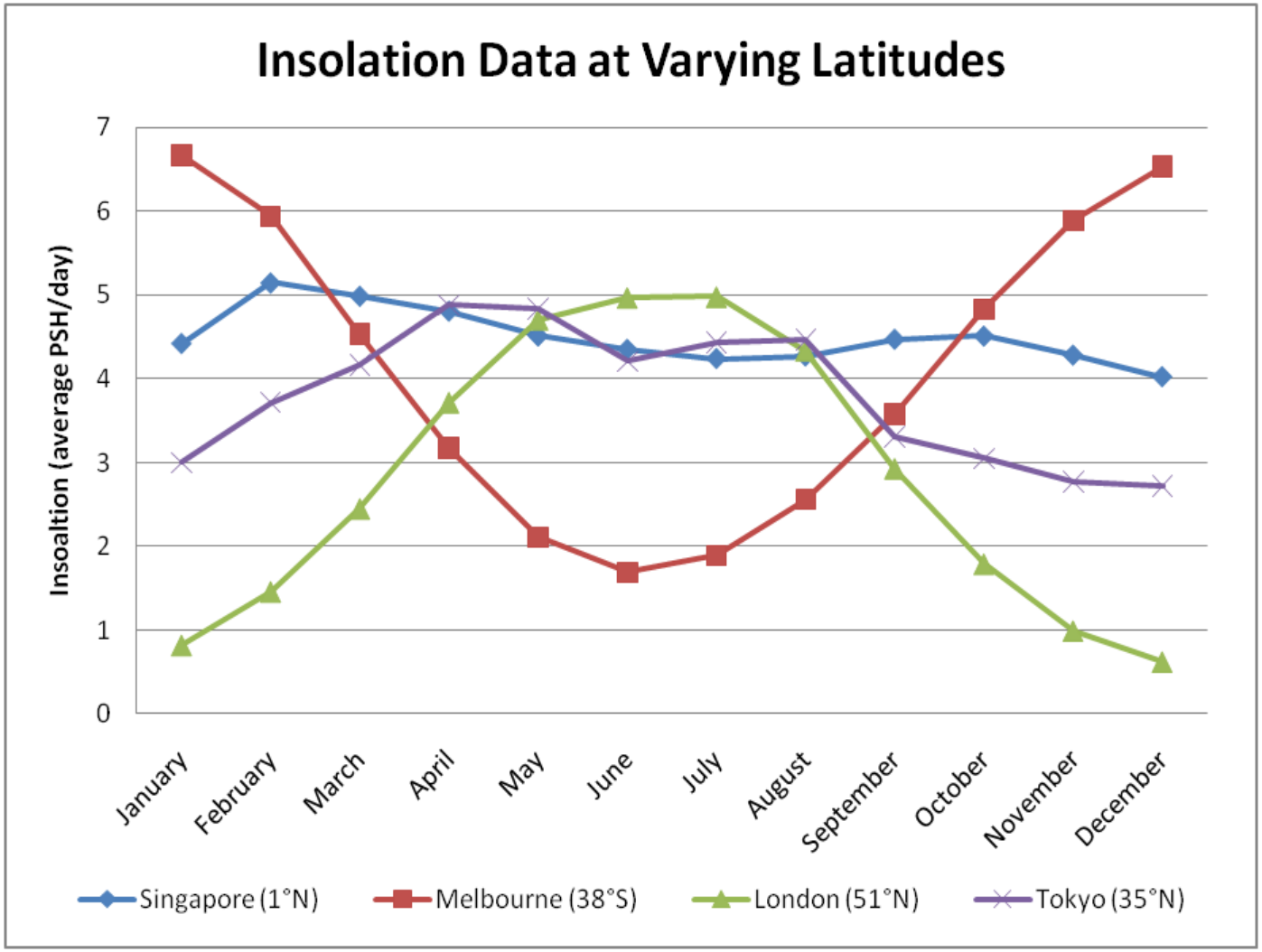
Variation Throughout the Year