It's not <u>always</u> cloudy in the Pacific Northwest: Characterizing the solar resource and solar irradiance variability

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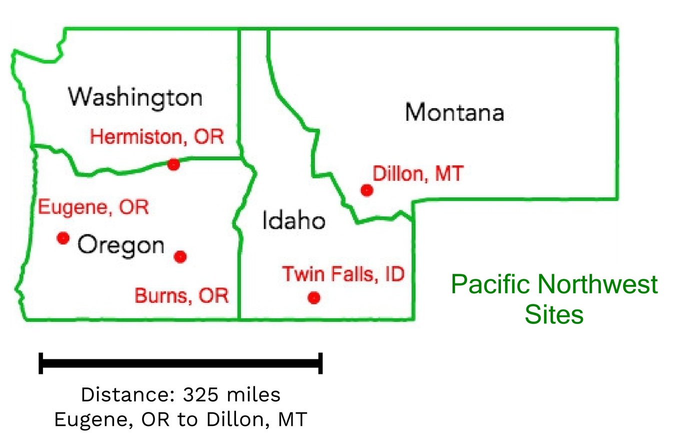
Motivation:

- ◇ Possibility of commercial solar energy production in the Pacific Northwest
- ◇ Information for power grid operators
  - → Understanding short term, spatial and seasonal variability
- ◇ Understand the effect of clouds and meteorological systems on the ground level solar resource

Solar Resource:

Site Locations:

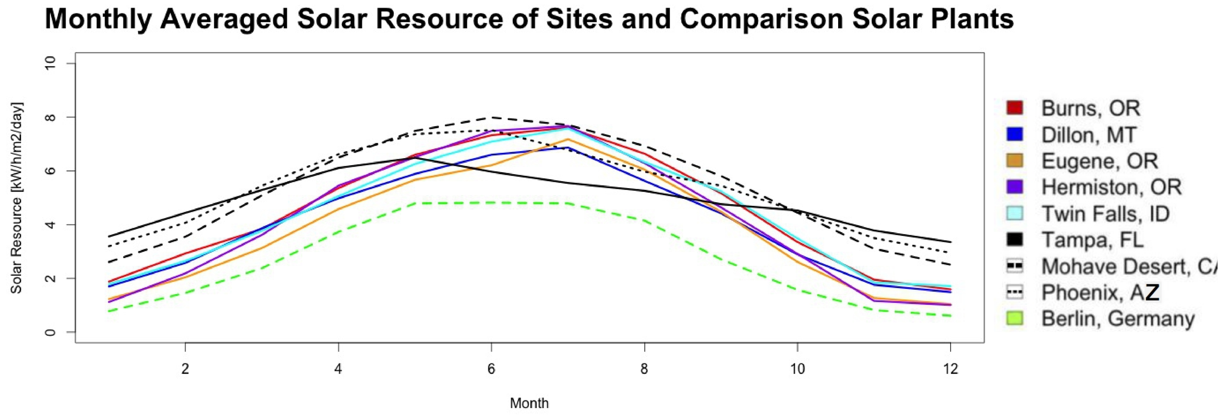


How much sun is there in the Pacific Northwest?

Site:	Yearly Averaged Solar Resource (kW/h/m²/day):
Burns, OR	4.53
Dillon, MT	4.08
Eugene, OR	3.81
Hermiston, OR	4.21
Twin Falls, ID	4.44
AVERAGE	4.32
Tampa, FL	4.92
Mohave Desert, CA	5.31
Phoenix, AZ	5.28
Berlin, Germany	2.71

http://solarelectricityhandbook.com/solar-irradiance.htm

Monthly Averaged Solar Resource of Sites and Comparison Solar Plants



Meteorology/Climate:

www.ocs.oregonstate.edu/county_climate

Burns, OR – el. 1265 m
Semi-arid high desert plains climate
Wet winters and late spring, driest from July to September

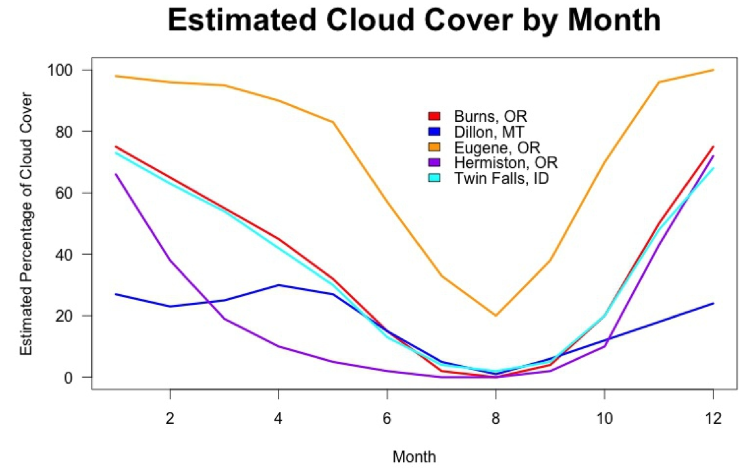
Dillon, MT – el. 1590 m
Intermountain valley climate
September driest month,
June wettest month

Eugene, OR – el. 150 m
Wet, lowland coastal climate
Cool wet winters,
warm dry summers.

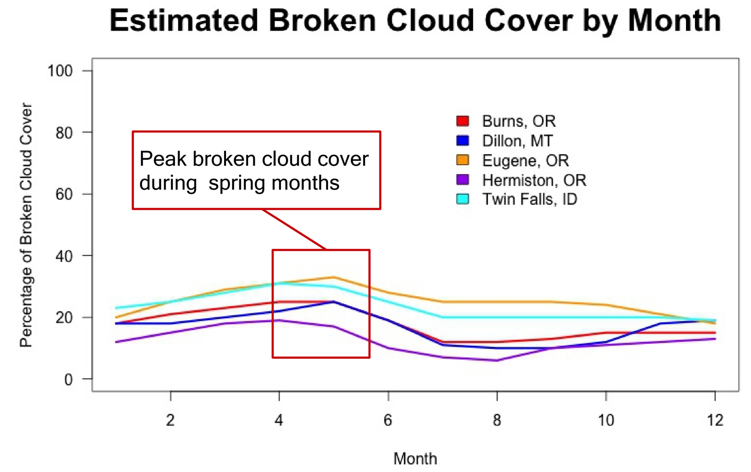
Hermiston, OR – el. 180 m
Semi-arid climate, moderated by the Columbia Gorge.
Wet winters, dry summers with localized thunderstorms

Twin Falls, ID – el. 1200 m
Semi-arid high valley climate
Wet winters, dry summers with localized thunderstorms

Estimated Cloud Cover by Month



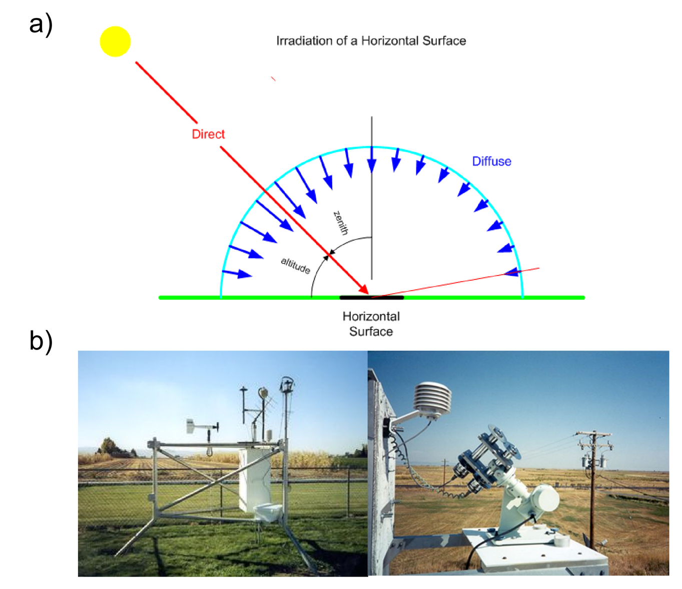
Estimated Broken Cloud Cover by Month



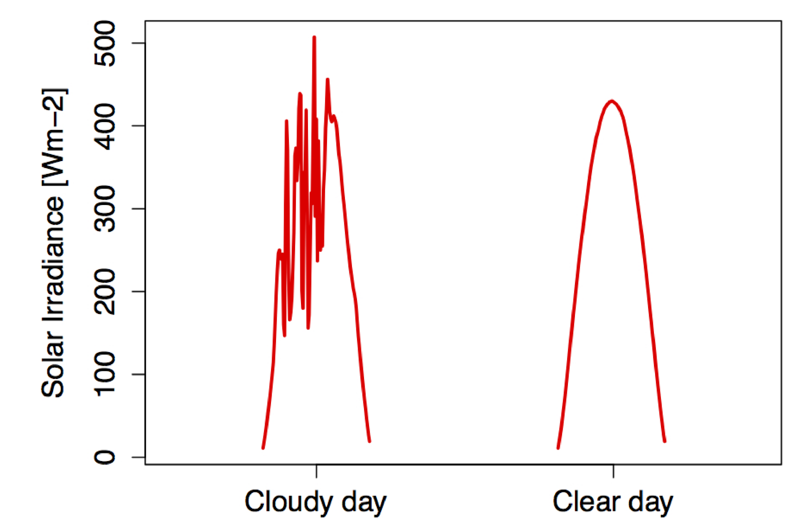
www.weatherspark.com

Solar Irradiance Variability:

Global Horizontal Solar Irradiance: (product of diffuse and direct irradiance)
The total flux of solar radiation energy reaching the Earth's surface.



a) Diagram of global horizontal solar irradiance
b) Instruments at Twin Falls, ID and Burns, OR sites



Solar irradiance of a cloudy and clear day using a 5 minute time series for January 5th (cloudy) and 6th (clear), Burns, 2003. Note the jagged pattern in the cloudy day plot, showing the increased variability caused by clouds.

Relevance of solar irradiance variability:

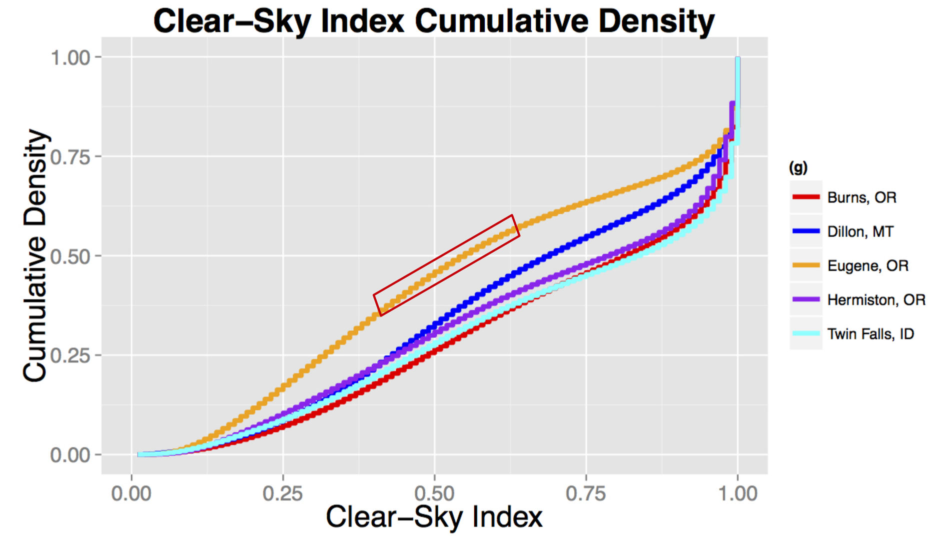
- ◇ <u>Solar energy variability</u> is much <u>greater</u> than nonrenewable sources.
- ◇ **Expensive barrier** for power grid system planners and operators
  - → Understanding variability is necessary for effective power grid management.
  - → Understanding effect of averaging sites (AVG) on variability aids decision making involved with constructing large photovoltaic energy systems.

Clear-Sky Index:

$$\text{Clear-Sky Index} = F_{measured} / F_{clear\text{-}sky}$$ Where F= Global solar irradiance

- <u>What percentage of possible solar energy is reaching the ground?</u>
- <u>What is the character of the cloud cover?</u>
  - → Eliminates the diurnal cycle of the solar resource, focuses the analysis on the effect of cloud cover

Clear–Sky Index Cumulative Density



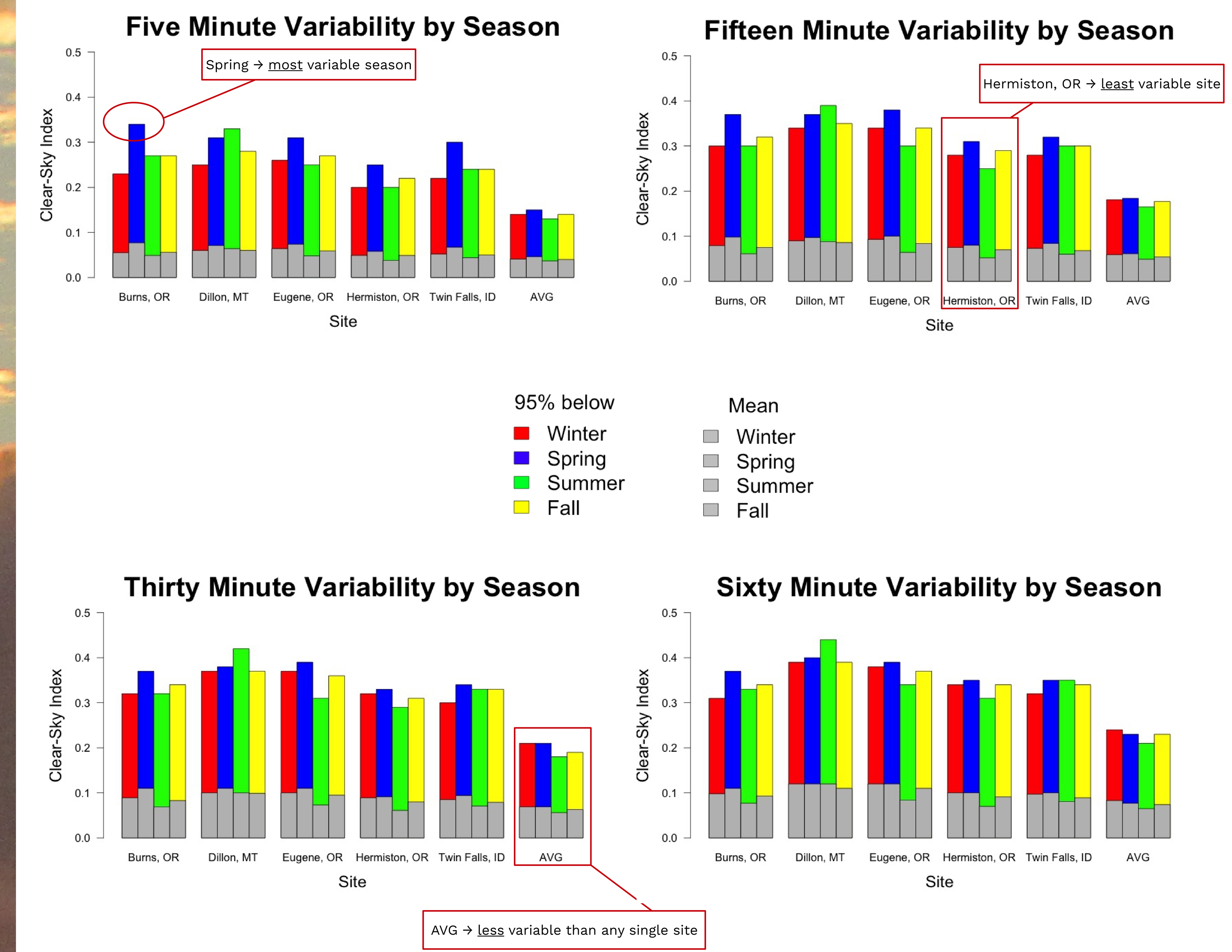
<u>Eugene, OR:</u>
Greatest occurrence of low clear-sky index
→ most consistent cloud cover

Methods:

Data : *University of Oregon Solar Radiation Monitoring Laboratory* *(http://solardat.uoregon.edu/index.html)*

- ◇ Five minute resolution global horizontal solar irradiance (GHI) time series from 2003 – 2014 measured using ground pyranometers at the listed sites.
- ◇ Data quality control retained only points marked as 'processed data'.
- ◇ Daytime defined as global solar irradiance values greater than 10 Wm^{-2}.
- ◇ Time series variability calculated by taking the difference between adjacent values within each time series.
- ◇ Clear-Sky Index values calculated based on expected clear-sky measurements (Long and Ackerman, 2000) for the years 2004-2013.
- ◇ Clear-Sky Index values for solar elevation angles less than 10° were removed from analysis due to high instrument error.

Clear-Sky Index Variability:



Conclusions:

☼ The Pacific Northwest solar resource is large enough for commercial solar power generating stations to be practical.

☼ While the yearly averaged solar resource is less for the Pacific Northwest than California, it is close to Tampa, FL and provides the advantage of greater values in the summer months (when CA needs more energy for cooling). Also, less extreme temperatures increase solar panel efficiency.

☼ Hermiston consistently has the least variable clear-sky index and reasonable total resource, making the location the most ideal for commercial solar power infrastructure.

☼ Averaging the sites results in decreased variability.
→ good for power grid operators

☼ Spring months contain the highest variability, likely due to the increased percentages of broken cloud cover.

☼ Variability increases between timescales of 5 to 60 minutes.

Acknowledgements and Resources:

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Long and Ackerman (2000), J. Geophys. Res.,doi:10.1029/2000JD900077
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