NV·GL

ENERGY

The Challenges of Selecting Solar Resource Data for a New Site

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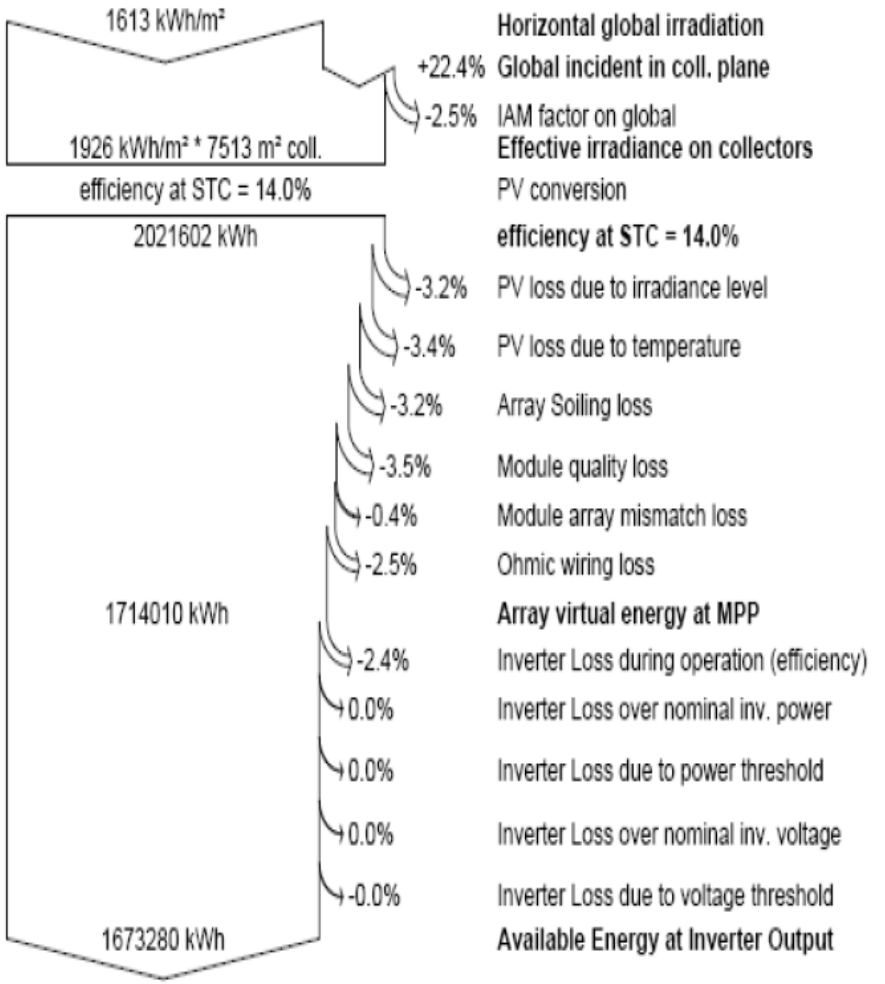
Purpose

- Photovoltaic Power projects are financed based on
  - Expected value of energy production over the project life
  - Downside estimates of generation (e.g. P90)
- What goes into estimates of generation?
  - Global Horizontal Irradiance (GHI)
  - Diffuse Horizontal Irradiance (DHI) is measured (rarely) or modelled (in the database or within the PV performance modelling software)
  - DHI is combined with GHI and a transposition model to obtain Plane-of-Array (POA) irradiance
  - POA Irradiance is the dominant input
  - Ambient temperature is important as well

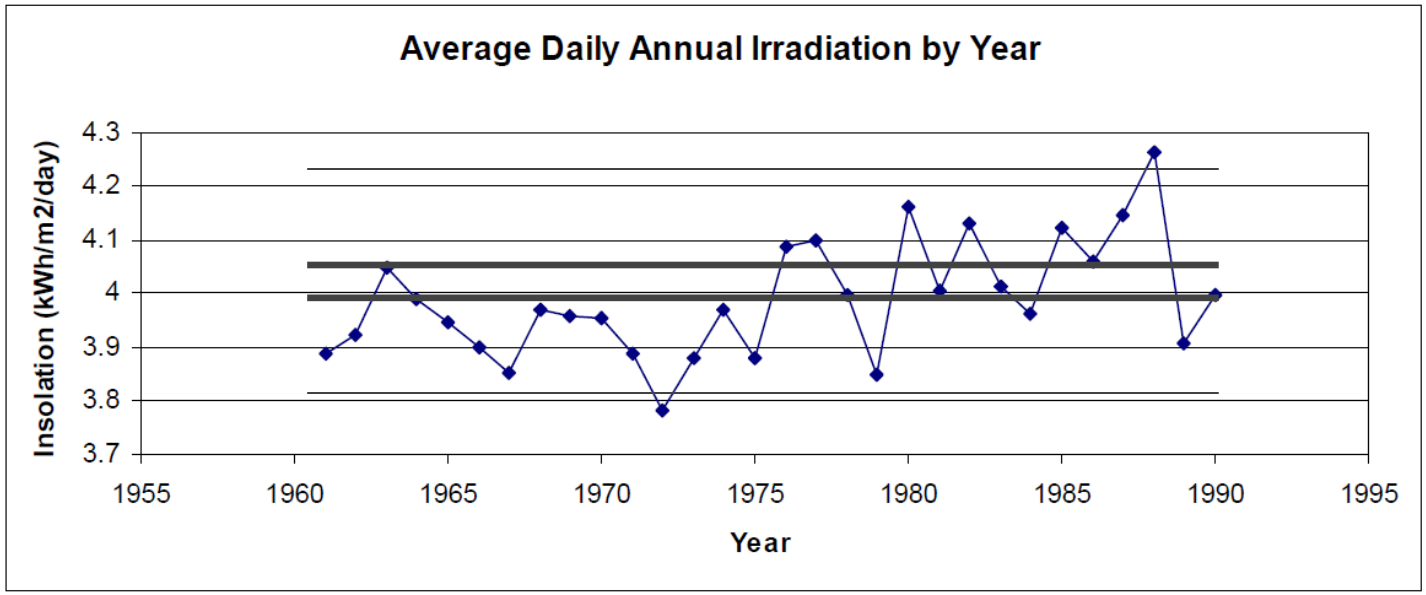


Sample Solar Resource Databases

- **NREL National Solar Radiation Database – NSRDB**
  - 30 years (1961-1990) hourly data, 239 sites, 56 primary Sites (have some ground measurements)
  - Secondary sites only have modelled data from reported cloud cover, humidity, etc.
- **NSRDB Update**
  - 15 years (1991-2005) hourly data, ~2000 sites, satellite images used to estimate cloud cover
  - Poor reliability 1991-1997
- **CIMIS**
  - 3-25 years (1985+) hourly data, California-only agricultural network with 200 stations
- **3-TIER**
  - 18 years (1997-current) daily data, 20km grid, ±66° latitude worldwide,
- **SolarAnywhere (NREL Solar Prospector contains a subset)**
  - 15 years (1997 to present), 10km or 1km grids, 1hr or 1min values
- **NASA-SSE**
  - 22 years (1983-2005) monthly data, 1degree grid
- **SolarGIS**
  - 29 years (1985-present) 15min samples, 0.09km at equator

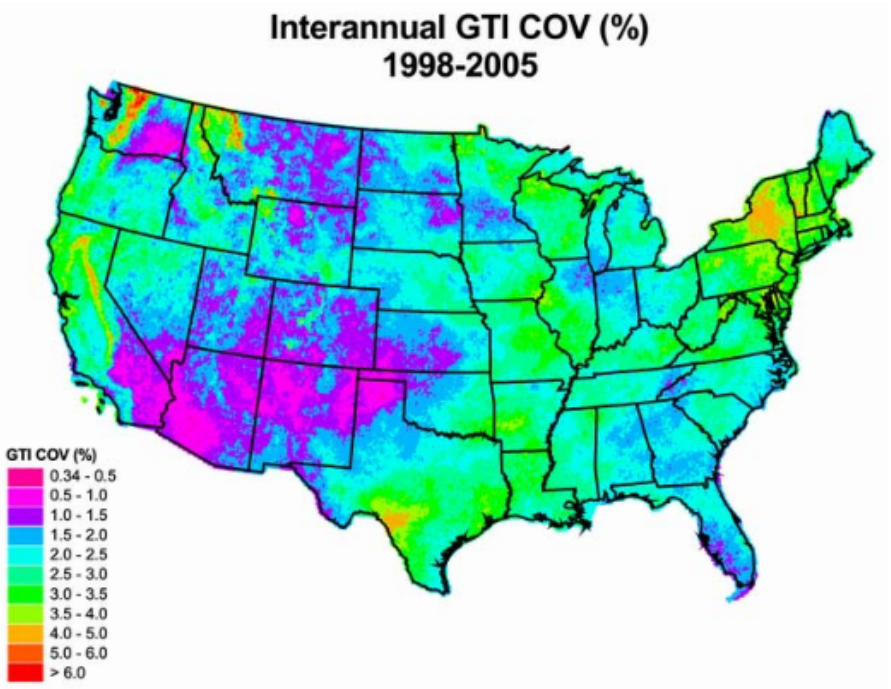
Variability

- Annual irradiation varies stochastically from year to year
- Even if you had a perfect instrument to measure the true value, you would still have to wait indefinitely to learn the true long-term average behaviour
- Instead, we use what data we have and bracket the long-term average with confidence intervals
- More years means smaller confidence intervals



Site-Specific Temporal Variability

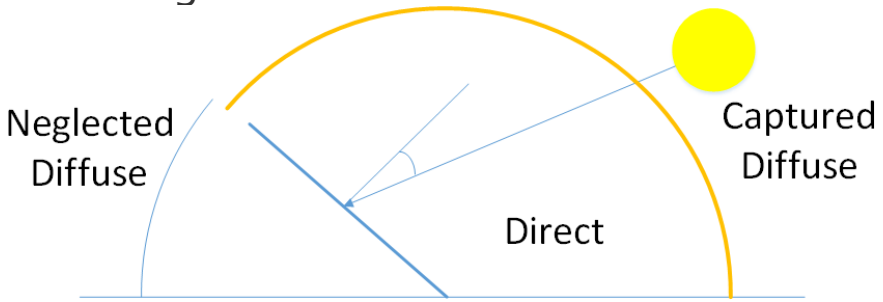
- Some areas have more variability than others.
  - Texas has surprisingly high variability over time
- Coincidentally (not), some locations in solar resource databases are more accurate than other locations
  - No one data source is likely to work in every location



(Gueymard and Wilcox 2009)

Orientation Affects Variability

- Keep in mind that tilted or tracking orientations:
  - Intercept more irradiation when the sun is out
  - Intercept LESS irradiation when the sky is cloudy
  - Bigger upside comes with a bigger (relative) downside!
- Site-specific, orientation-specific measurements need more years of data to get similar relative range of confidence as GHI
  - POA is valuable for monitoring installed PV equipment
  - For prospecting, there is a high risk that implemented orientation will change
  - GHI can be correlated with more alternate sources without introducing transposition modelling error

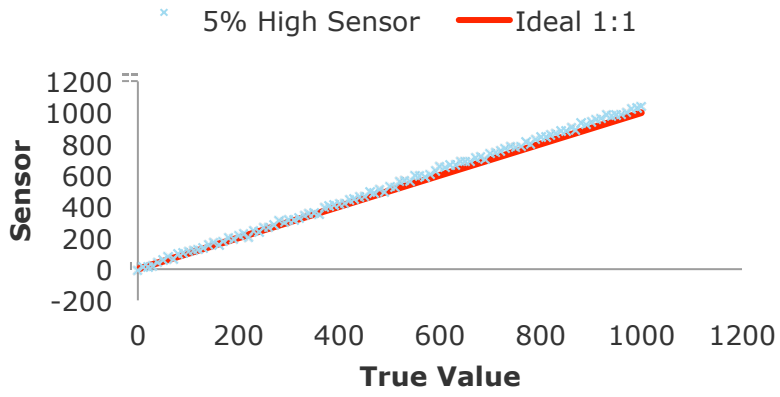


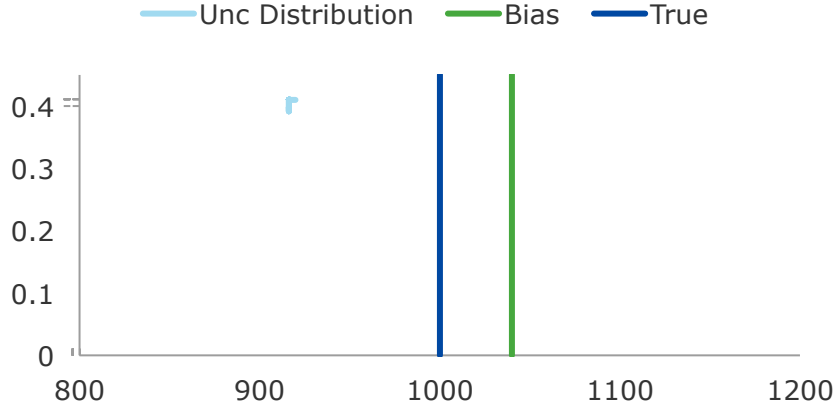
Onsite Measurements… Rarely Long Enough

- Sometimes a developer will start measuring irradiation before the project begins
  - Is one year enough? (perhaps)
  - How about 2 months? (unlikely)
- Alone, the usefulness of this data is constrained by the variability problem
- If low-accuracy equipment is deployed, or the instrument is not cleaned then it may also yield uncertain data
  - Maintenance is as important as equipment class

Uncertainty

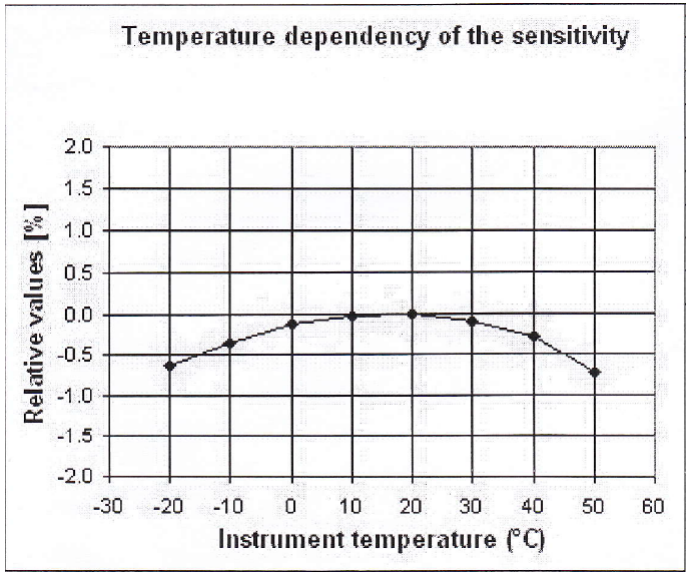
- How far is this measure likely to be from the right answer?
  - Typically expressed as a range which is expected to contain the right answer
  - Range should include an expression of confidence, because there is always some chance that the right answer is outside the specified range
  - Uncertainty should be provided by the source, but is not always
  - "Truth" is hard to compare with... normal practice is to calibrate an instrument against a more accurate instrument and estimate the uncertainty of the more accurate instrument

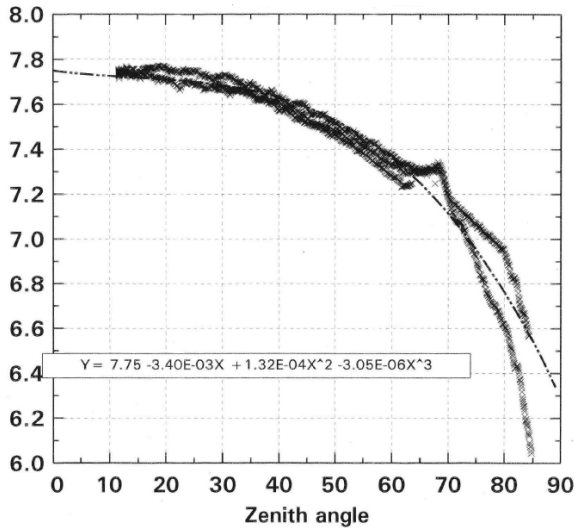




Uncertainty Is Not Necessarily the Same at all Times

- NSRDB quotes Hourly uncertainty values 6-25%
  - Includes incidence angle calibration sensitivity, which has been known to vary by 5% but the actual impact depends on time, latitude and diffuse fraction
  - Modern secondary standard instruments are not that sensitive to incidence angle (<2%), but First or Second Class instruments may be



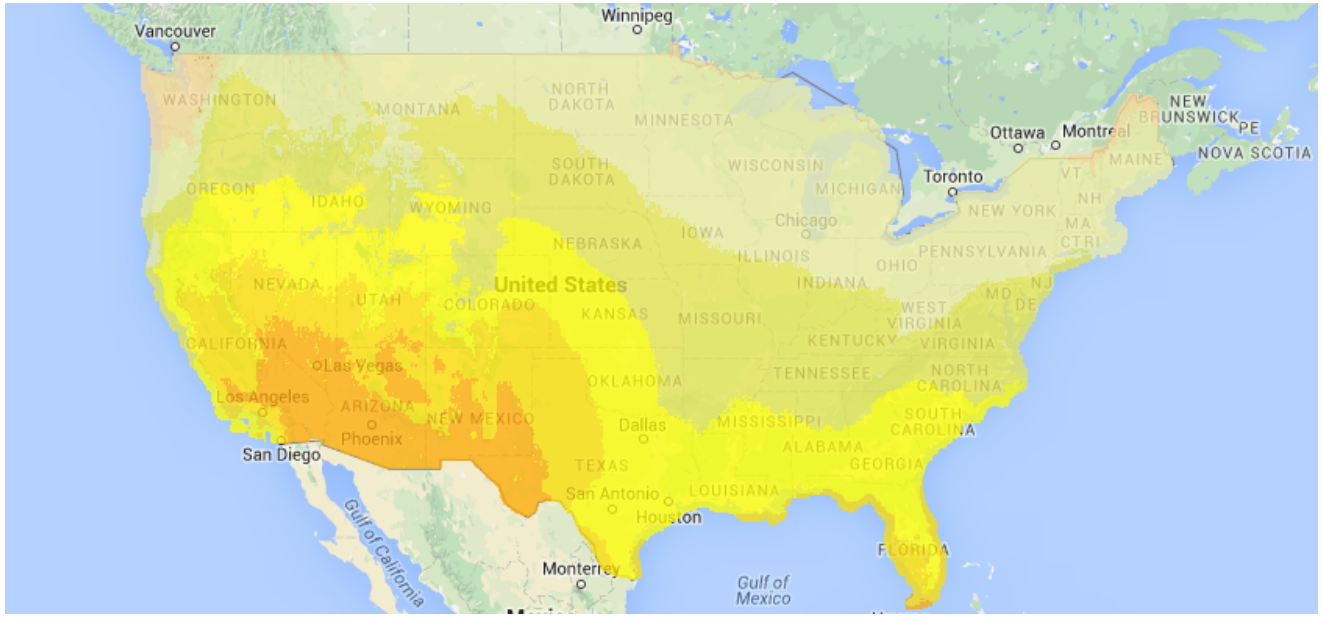


Uncertainty Over Time

- A short-term bias error can become a long-term variation that partly cancels out plus a bias that does not cancel out
- Estimates made over short intervals are likely to have higher uncertainty (10%) than estimates made over long intervals (6%?)
- How much of the hourly uncertainty is bias?
  - If bias error is small, then averaging helps (10% hourly → 3% annual)
  - If bias error is large, averaging is less helpful (10% hourly → 8% annual)
- Myers et. al. suggest bias can be small in some cases
  - Myers 1989 estimated 4% for laboratory grade outdoor measurements
  - Myers 2009 showed most instruments delivering bias less than 4% annually (at a manned facility)

Uncertainty Over Distance

- How far away does a measurement have to be before it is no longer useful?
- Depends on your local conditions
  - In many good sun locations spatial gradients in expected irradiation are small... hundreds of miles may be feasible
  - Near a mountain or coastline 5 miles may be the limit



Solar Prospector GHI Map

Spatial Averaging

- Satellite data sources provide estimates that apply to many square kilometers
- Ground sensors (and most PV arrays) are "point" measurements
- Primarily of concern in short duration data (i.e. forecasting), though mountains and coastlines can be a problem for historical data
- Can create artificial "step" changes at grid boundaries

Site-Specific Calibration

- Satellite data suppliers are accumulating a longer history
  - Weak on local calibration
  - Claimed strength in shape of historical trend and contemporary data collection
- Local ground-based measurements have short history
  - May be well calibrated
  - Can overlap in time!
- Use overlap to recalibrate satellite ground to calibrate satellite during overlap, assume calibration applies to all of history

Site-Specific Calibration Dangers

- Overfitting + Extrapolation
  - Ground measurement may easily be biased 2% high with good equipment
  - Satellite instrumentation may drift or be swapped out or albedo may change, with profile being 2% lower during the overlap than the rest of the profile
  - Estimated long-term value may be biased 4% too high!
    - ... Or not... but the uncertainty is difficult to eliminate because there are so many contributors.

No Magic Answer

- When all sources of error are considered, most data have
  - In specific cases, quality problems such as soiling, missing data, or large calibration shifts may be apparent in the trend... do not blindly compare such data with other sources
- Where the data sources are independent and show no obvious quality problems, errors should be uncorrelated
  - Central tendency of multiple sources of data should reduce uncertainty of estimate if the mean is used as the benchmark
  - To maintain correlation of weather variables, we normally choose one data source with irradiation near the mean of all valid sources
- As multiple new sources with lower uncertainty build history, older lower-quality sources may lose relevance.

References

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