Combining Satellite and Ground Data: What Works & What Doesn't

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Acknowledgements

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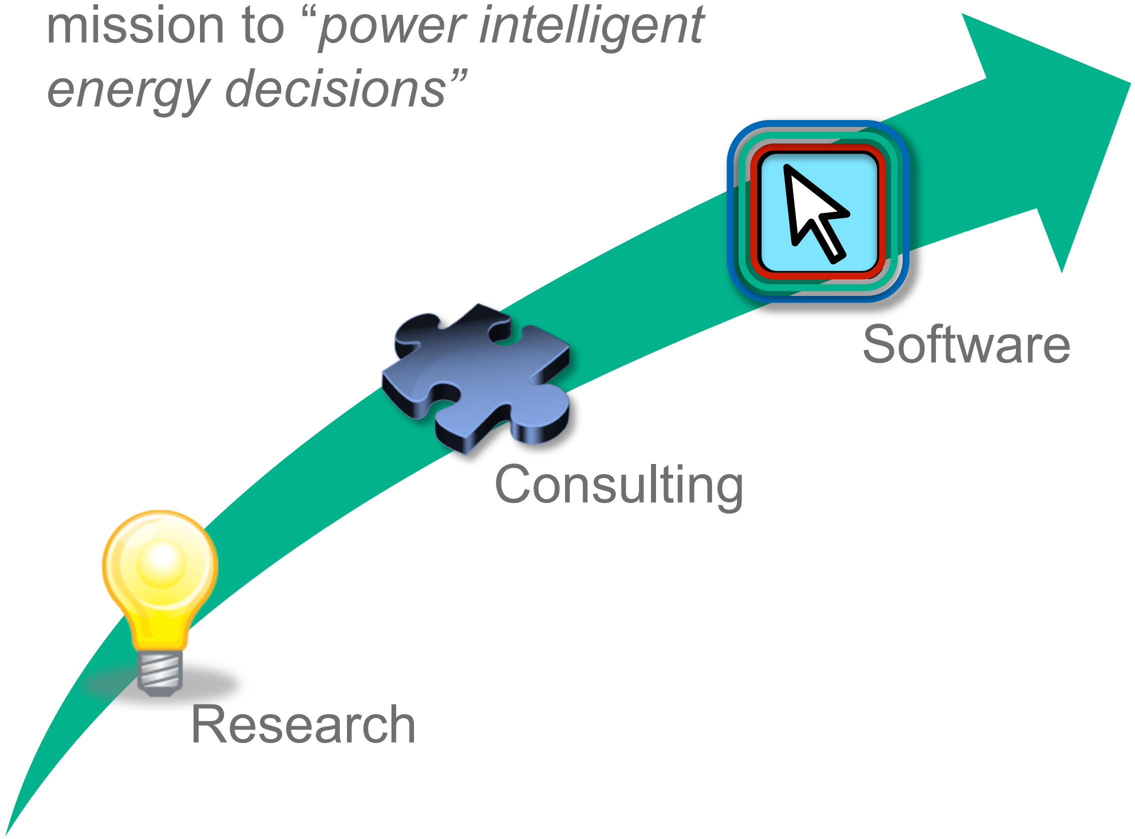
Founded in 1998 with the mission to "*power intelligent energy decisions*"



SOLAR PREDICTION

Most widely used solar resource database

PROGRAM OPTIMIZATION

~6.0 GW of renewable incentives processed

ENERGY VALUATION

>30 million solar estimations performed

Today's Discussion

- What Data Should I Use?
- Ingredients Needed for High-Accuracy Solar Resource Assessment
- Optimizing Ground & Satellite Data
  - Case study
  - What works and what doesn't
- Conclusions

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Which Dataset Should I Use?
Conclusions from 2014 Sandia Conference

Use Cases	TMY/ TGY	Ground	Satellite
Initial Estimates	✓		
Siting & Financing of Utility Scale PV Systems		✓	✓
Production Guarantees for DG Lease Funds			✓
Real-time Monitoring		✓	✓

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Ingredients Needed for a Dependable Solar Resource Assessment

- PV system details, near/far shading, soiling characteristics, etc. (site details)
- Solar resource (fuel)
- Ancillary inputs (air temperature, wind speed, precipitation (rain/snow), humidity, etc.)

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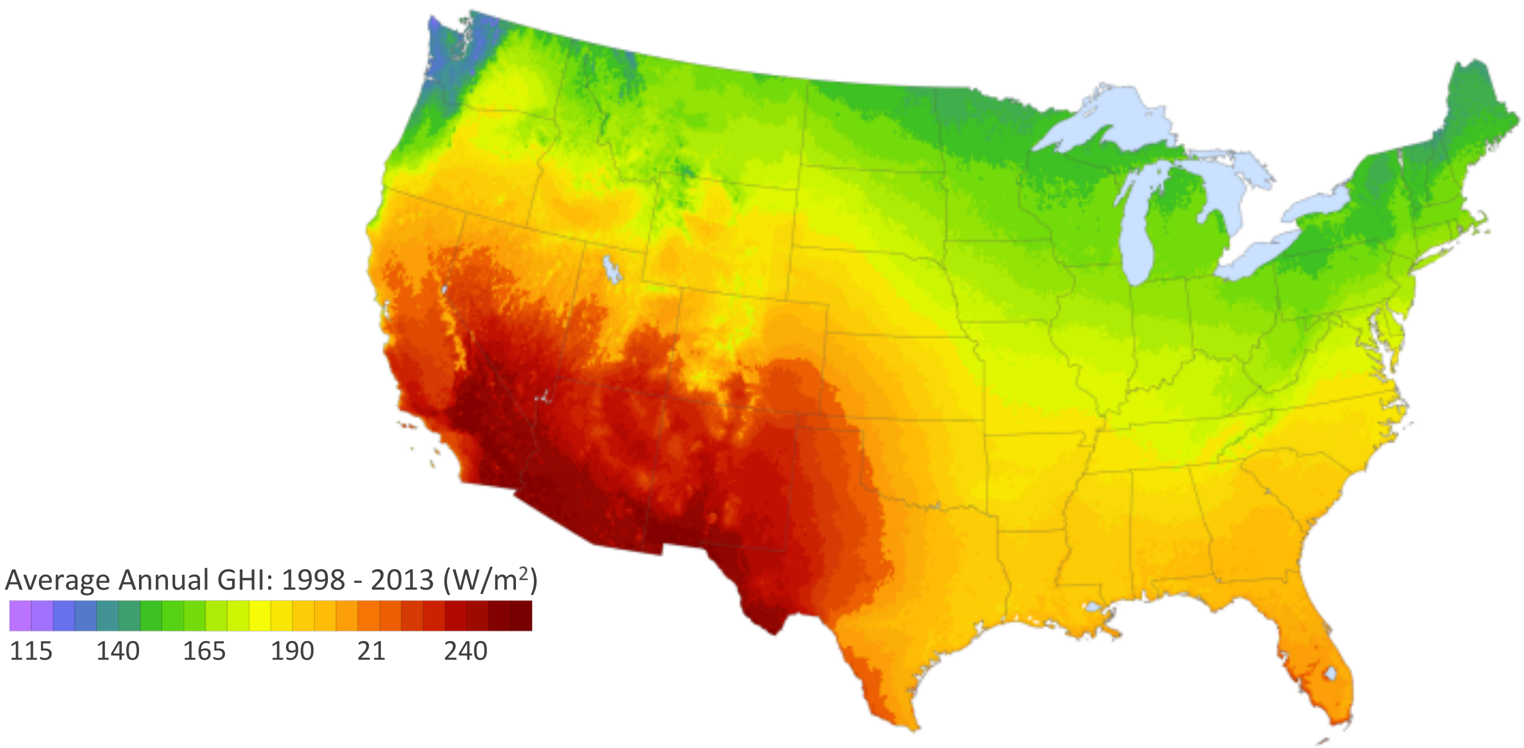
Solar Resource: Foundation for All PV System Simulations



Satellite-based solar irradiance models

Advantages:

- Continuous geographical coverage (1 km resolution)
- Temporally solid and consistent (17+ years)
- Up to 15 minute frequency observations
- Site-specific historical weather observations

Limitations:

- Lower accuracy (than high quality ground observations)

Value of Ground-based Solar Resource Monitoring

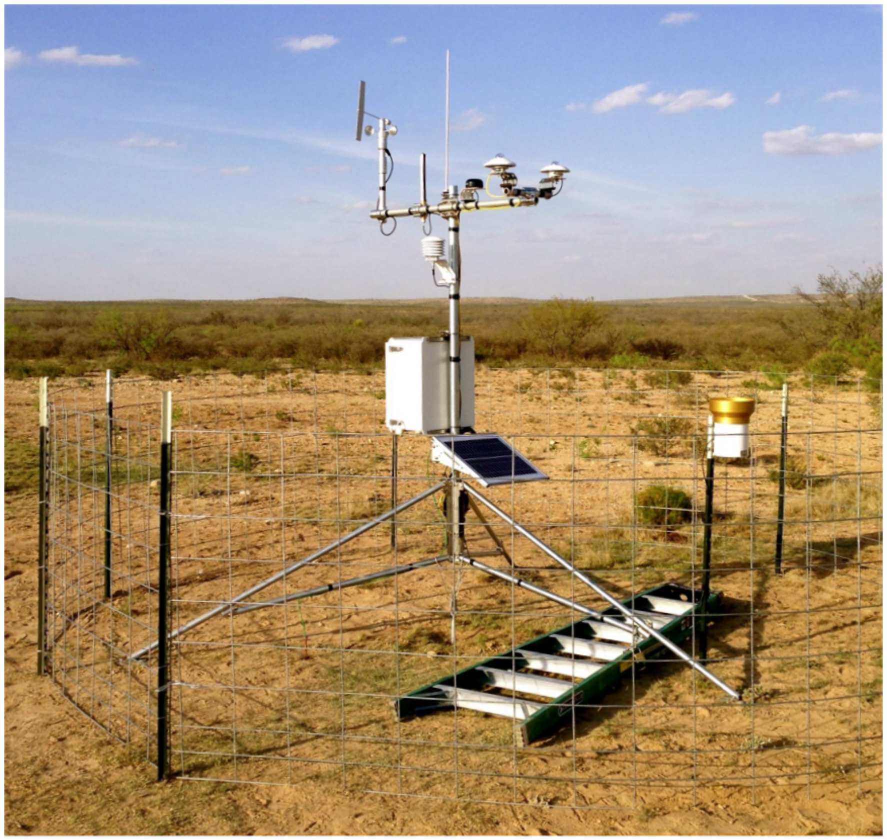


Image courtesy of GroundWork Renewables, Inc.

- High accuracy if properly maintained (dust, frost, snow, birds, event logging, etc.)
- Necessary to understand local variability effects
- Requires meticulous data QC
- Ground truth for tuning process
- Have to place into long term reference frame for proper resource context!

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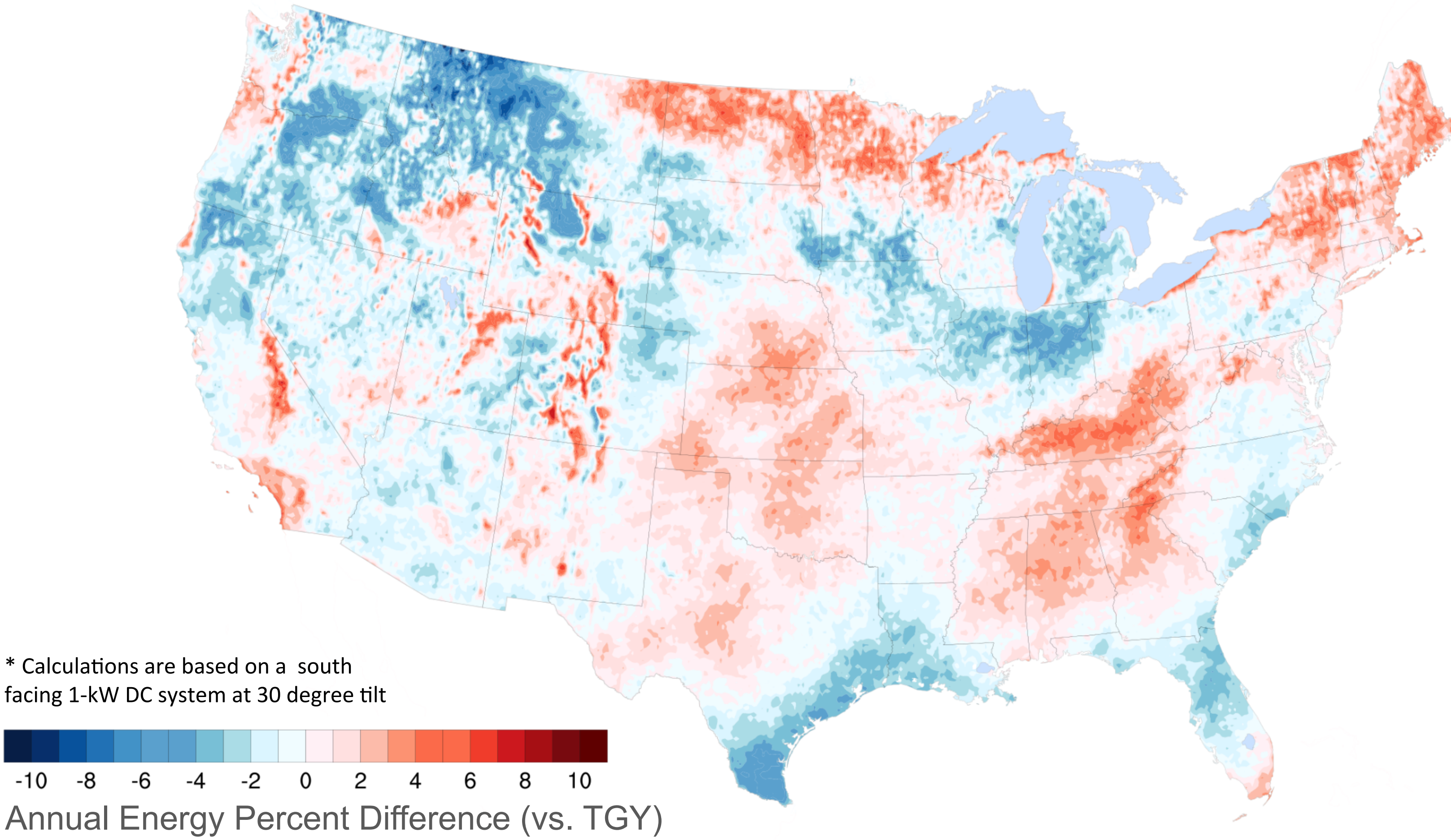
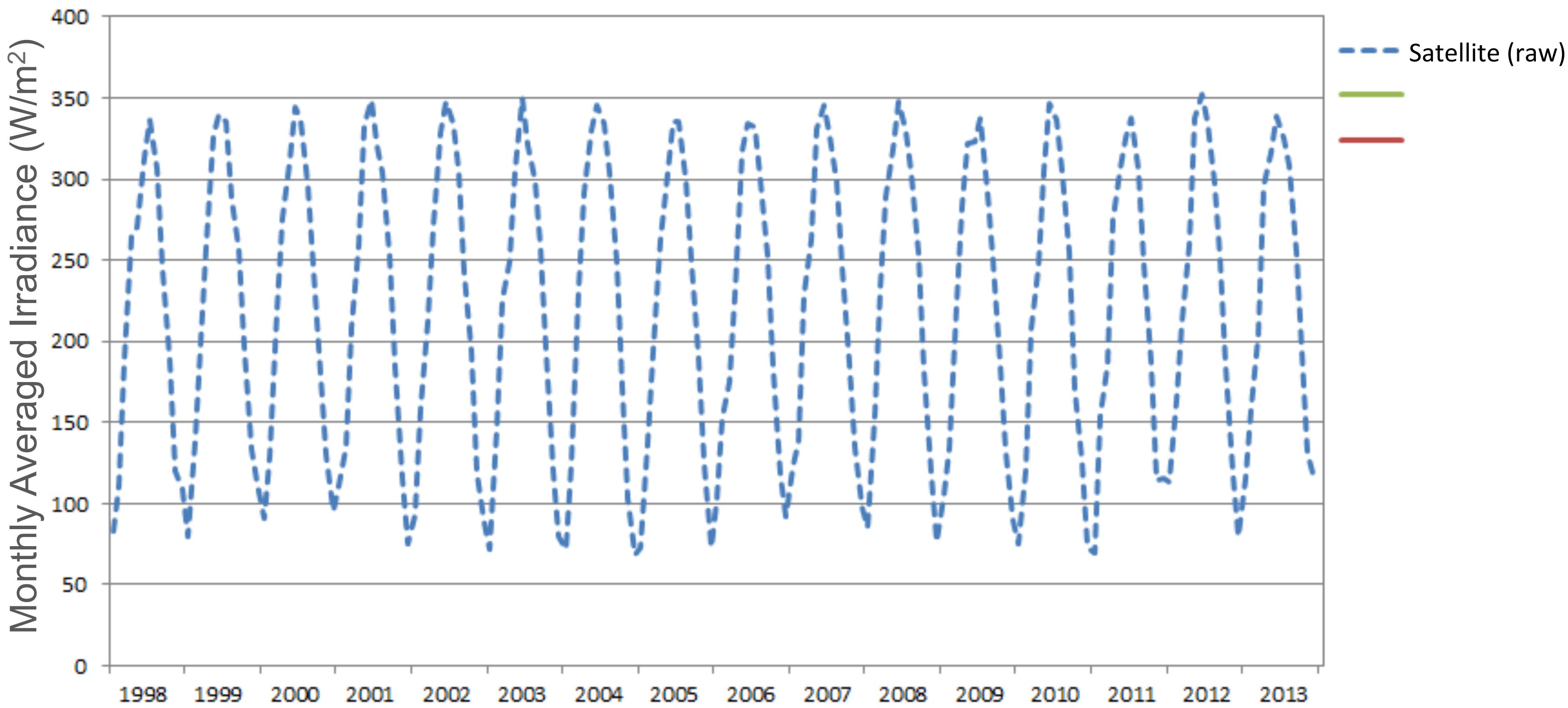
2014 Annual PV Production Variance*



* Calculations are based on a south facing 1-kW DC system at 30 degree tilt

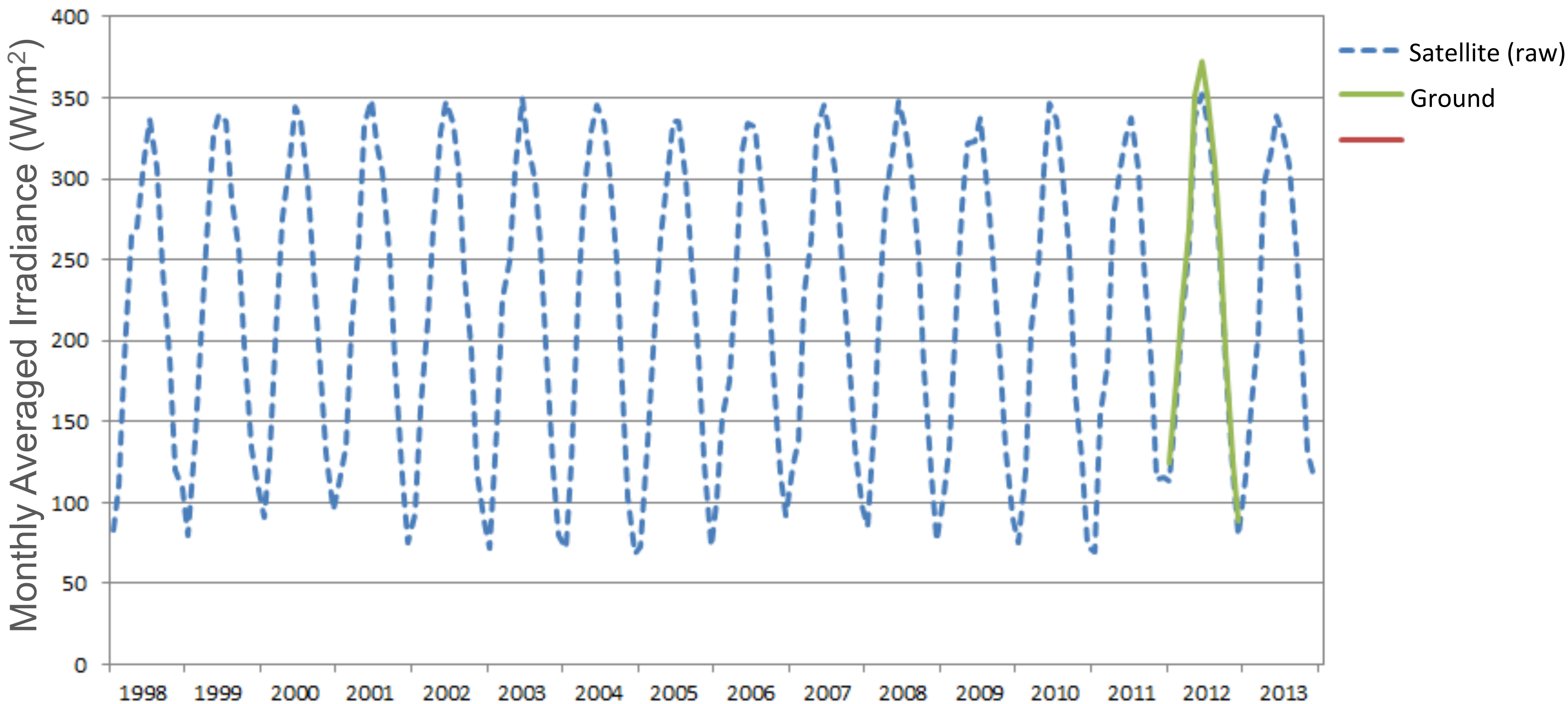
Need to place on-site measurements into long term reference frame due to year-to-year variability

Low-Uncertainty, Long-term Solar Resource Dataset



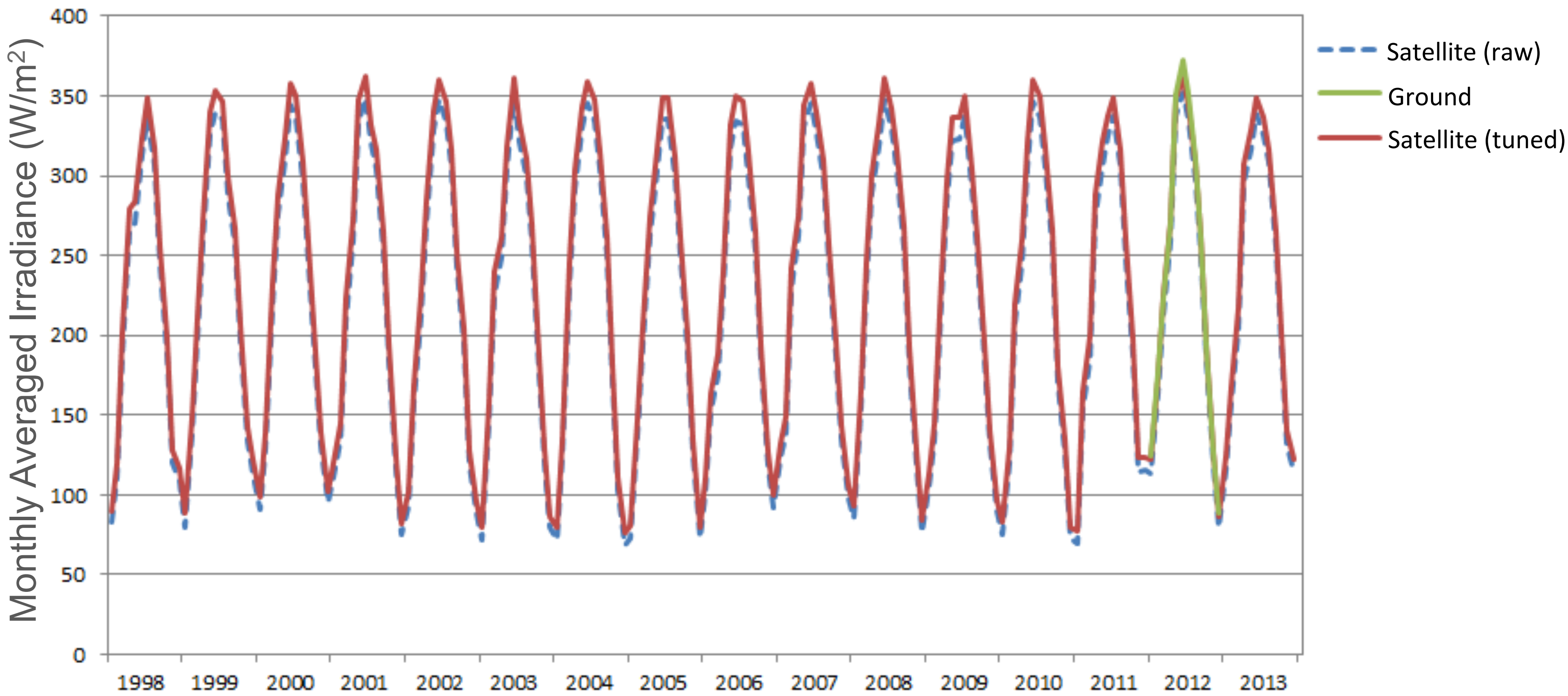
Satellite data

Low-Uncertainty, Long-term Solar Resource Dataset



Satellite data + quality ground data

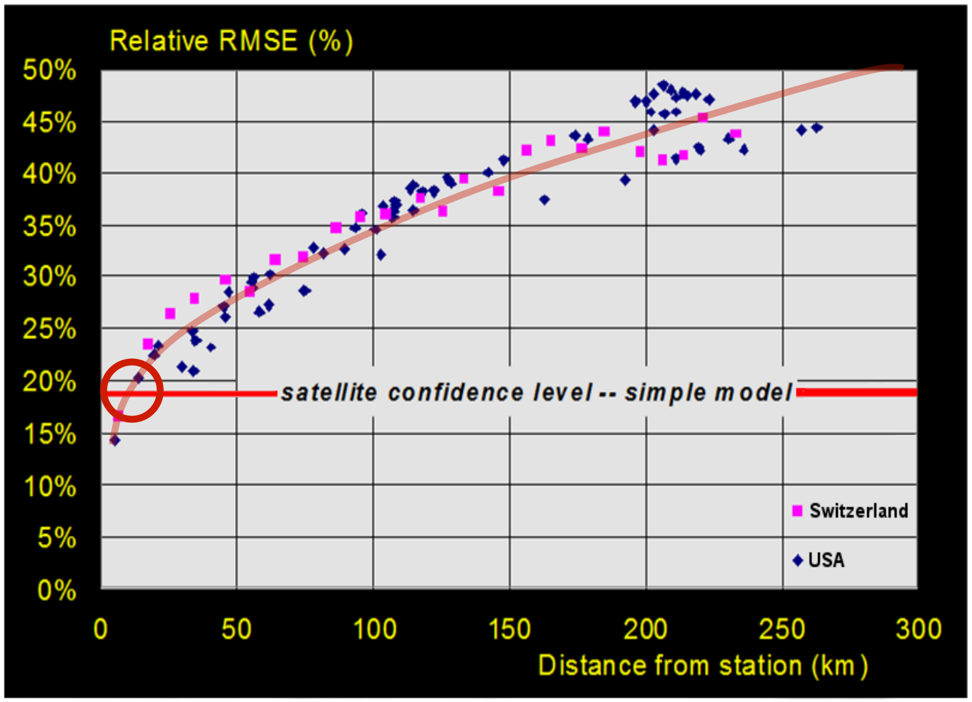
Low-Uncertainty, Long-term Solar Resource Dataset



Satellite data + quality ground data + intelligent tuning methodology
= most reliable long term solar resource

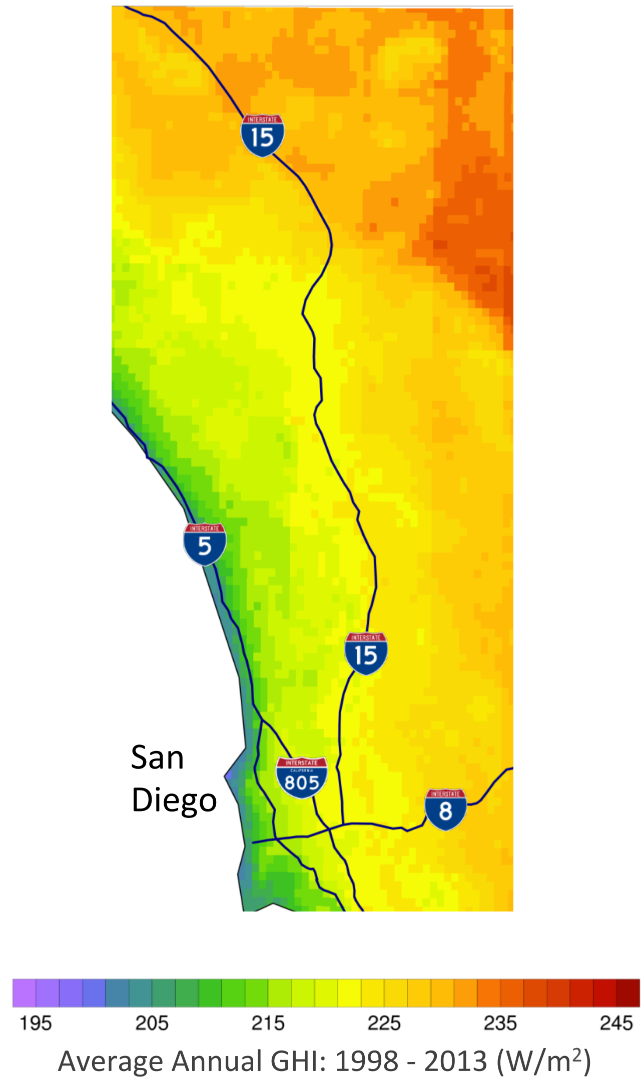
(P50, P90, inter-annual variability, etc.)

Ground Data Usefulness Degrades with Distance



Ground data are suitable at distances up to 10-25 km from project site (can be <5 km in regions with variable topography)

1 km SA TGY data



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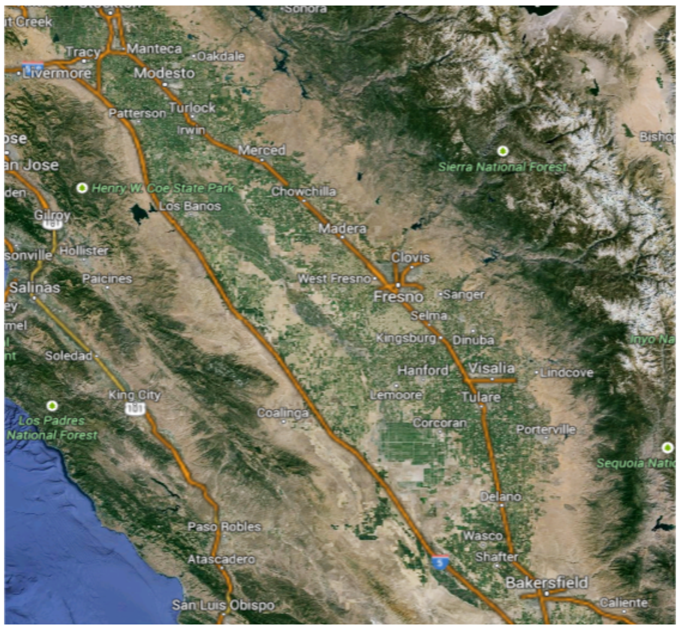
Case Study: PV Prospecting Site

Arid Desert Climate Site



High-Quality Ground Data (12 months)

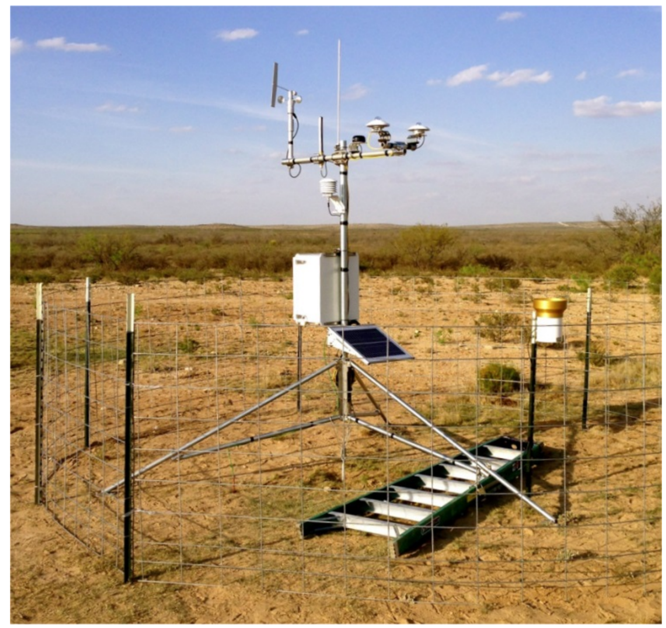


Image courtesy of GroundWork Renewables, Inc.

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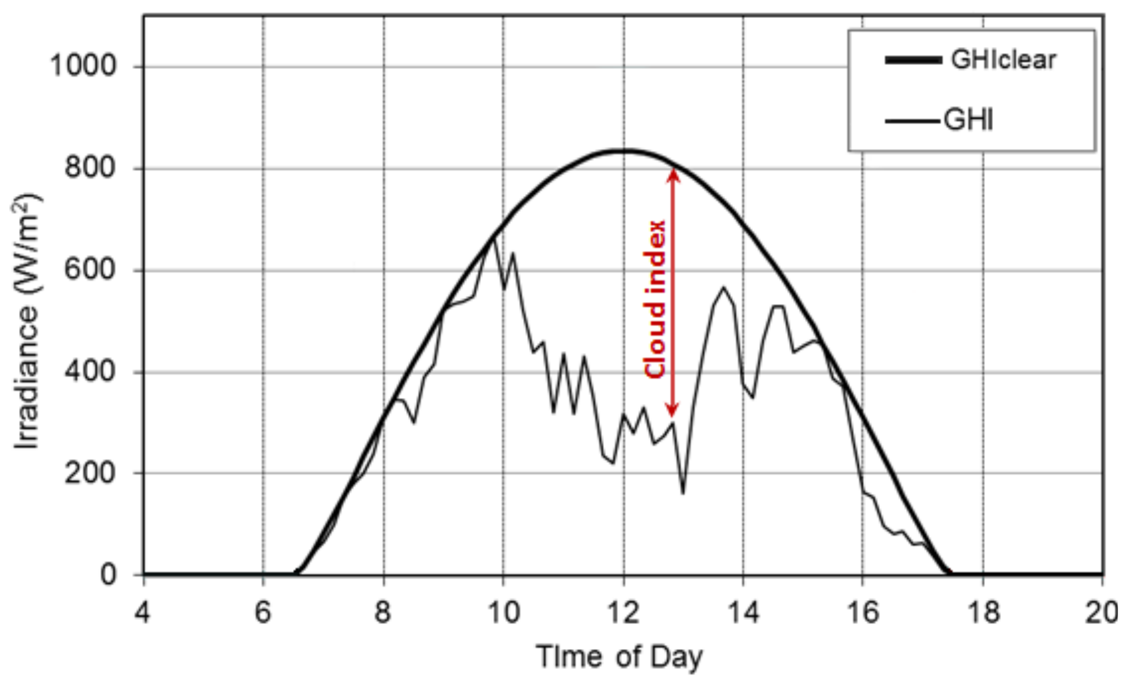
Understanding Differences: Satellite and Ground Datasets

Sources of satellite-model and ground irradiance differences:

- Clear sky bias (AOD, etc.)
- Seasonal (winter v. spring, etc.)
- Cloudy sky measurement error (satellite/ground mismatch, etc.)

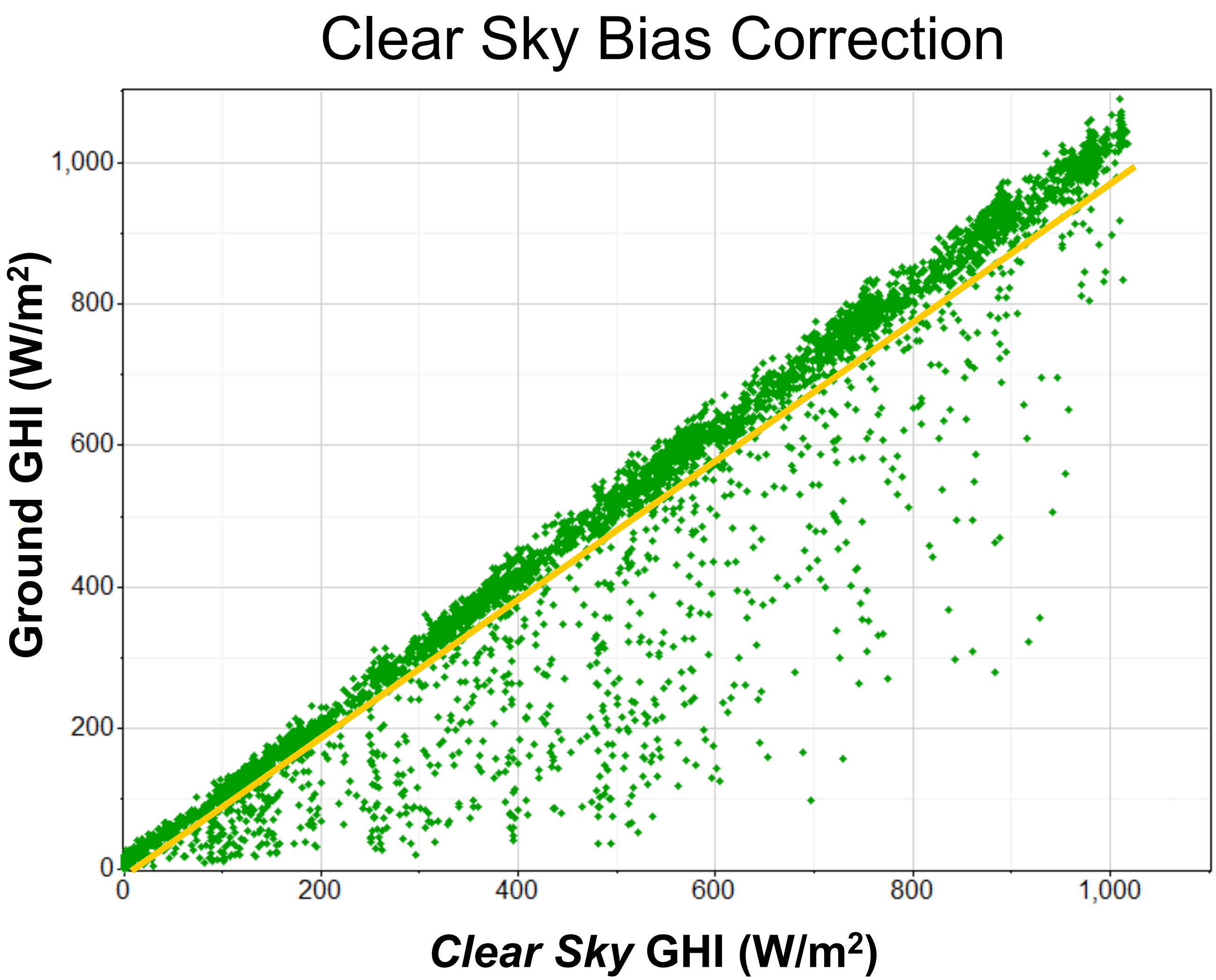
Other considerations:

- Irradiance rebalancing
- Ancillary data



Differences need to be targeted individually during the tuning process

Tuning Satellite Data with Ground Observations: Clear Sky Corrections



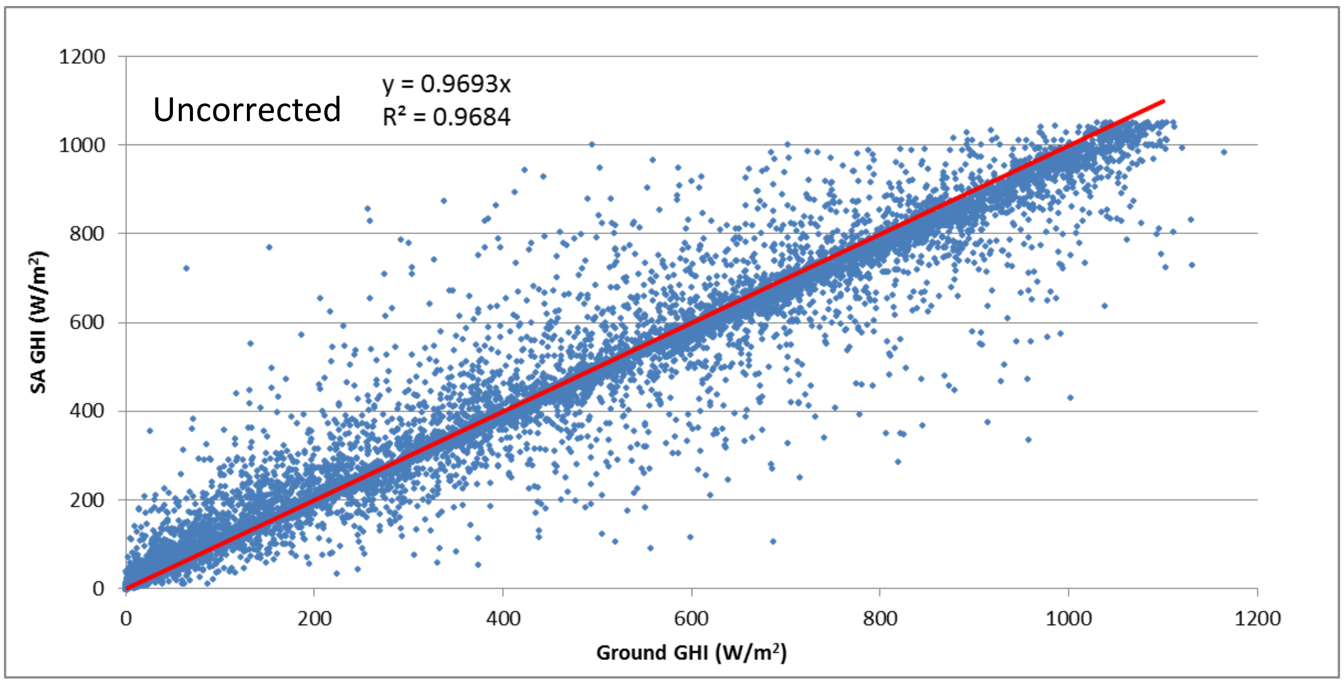
Overall Bias: 4.6%
Clear Sky Bias: 4.1%

Non targeted bias corrections would over correct in this situation

Addressing Clear Sky Bias Only

High quality ground data versus SolarAnywhere ("SA") satellite data

	rMBE
Overall	-0.59%
Clear Sky	-2.71%



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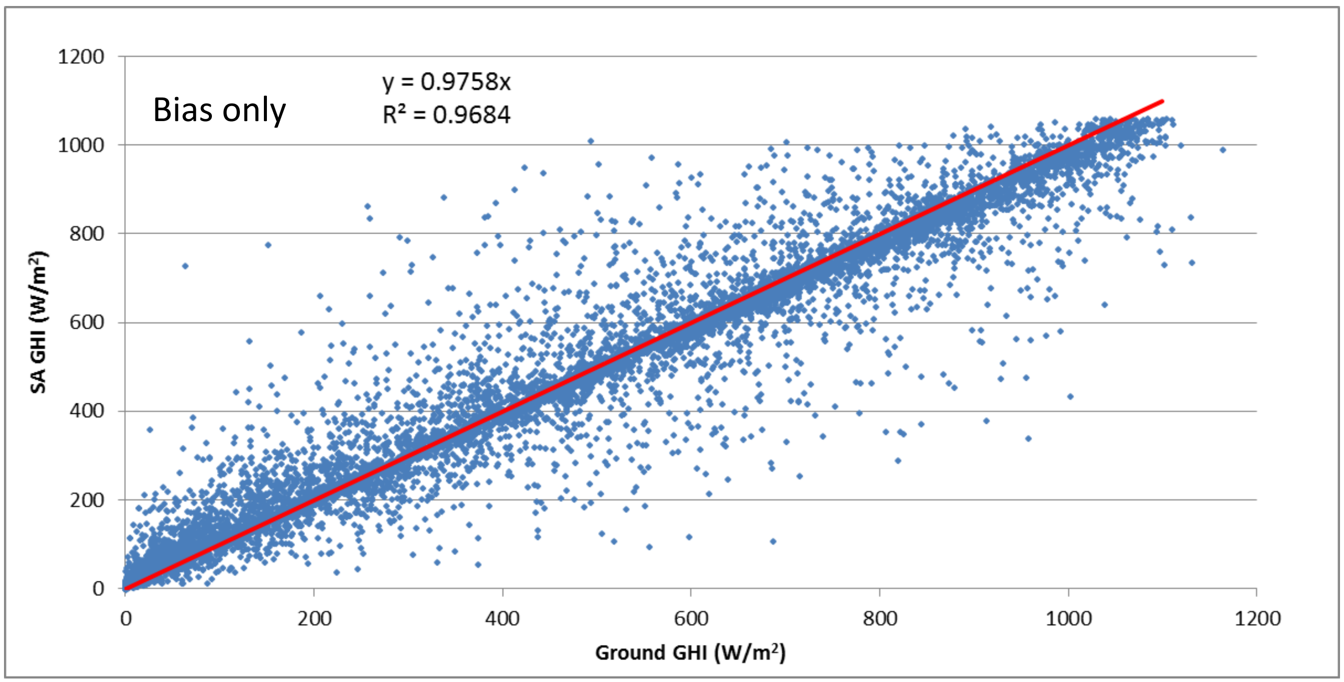

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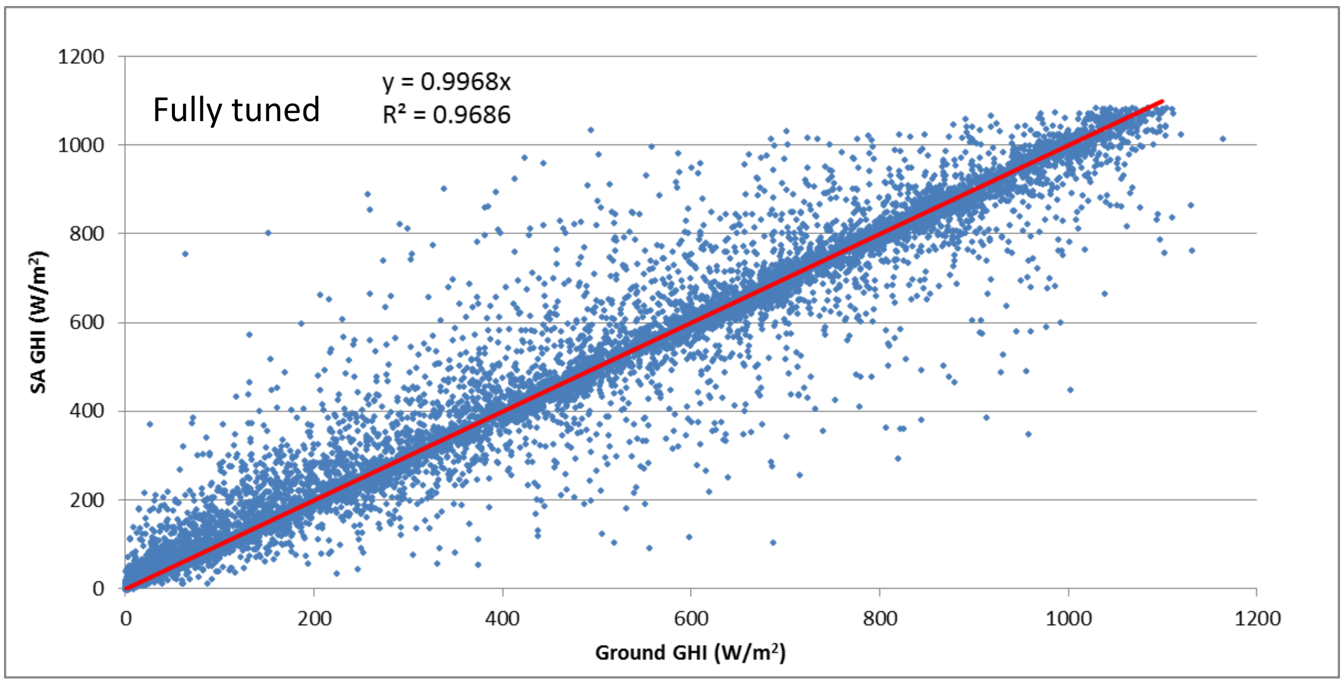
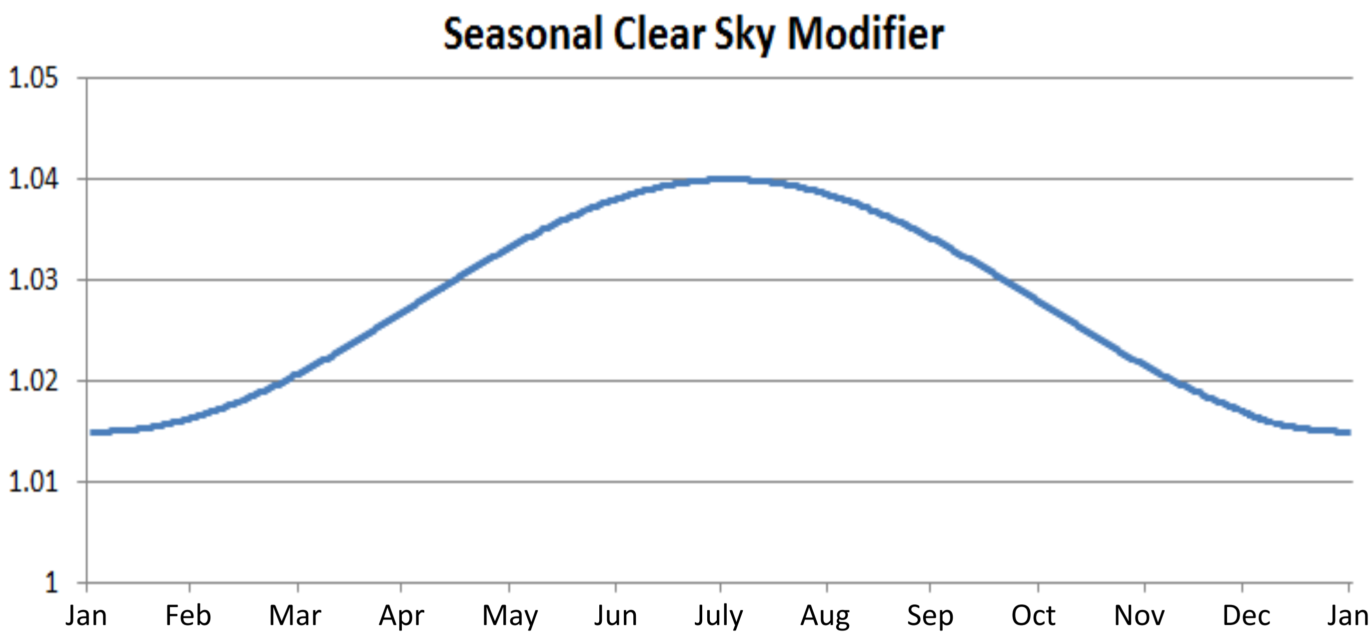


Targeting clear sky conditions addresses intrinsic measurement source errors

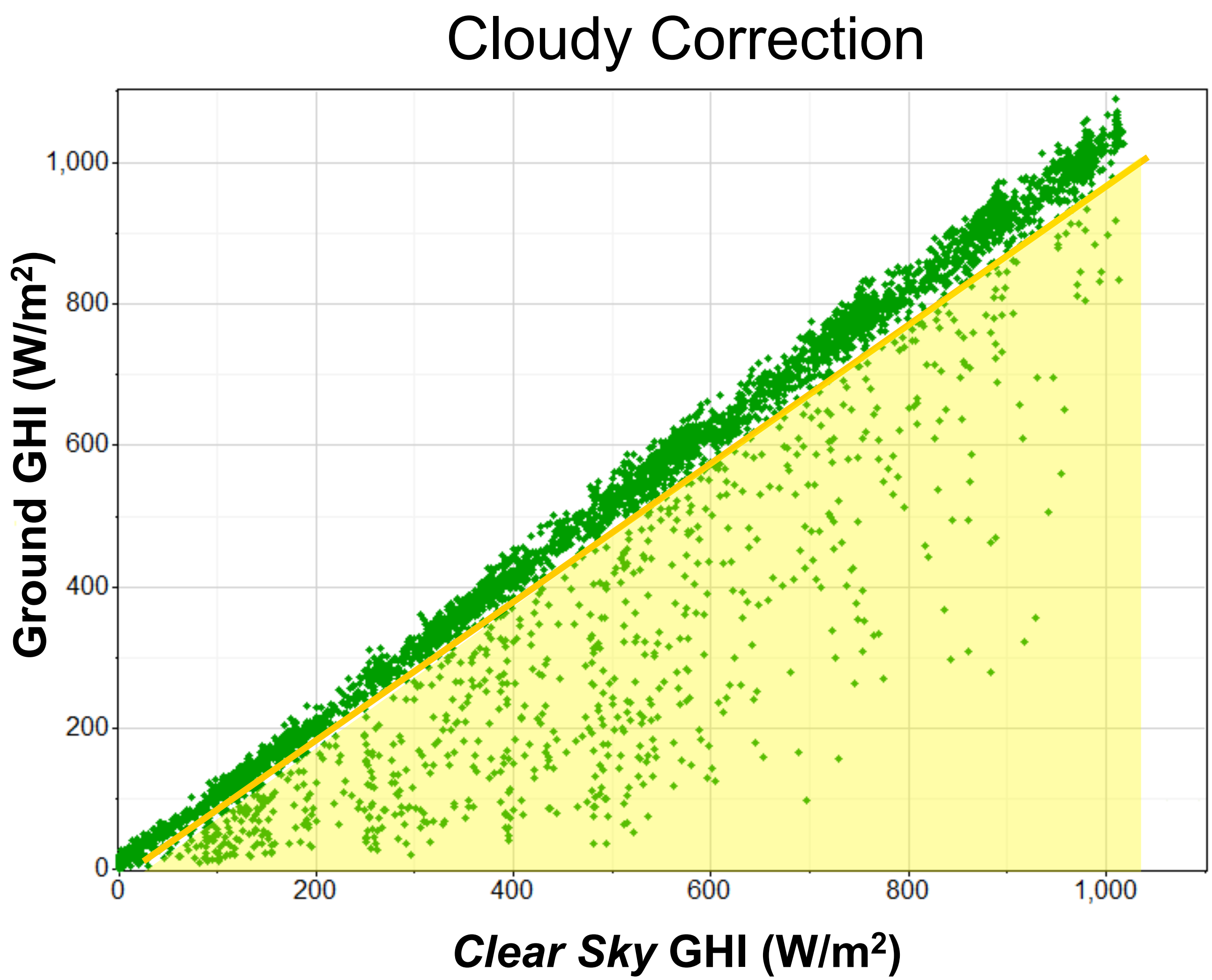
Tuning Satellite Data with Ground Observations: Seasonal Clear Sky Corrections

Can correct for seasonal clear sky biases with year+ of ground data observations



Seasonal impacts occur over the full year

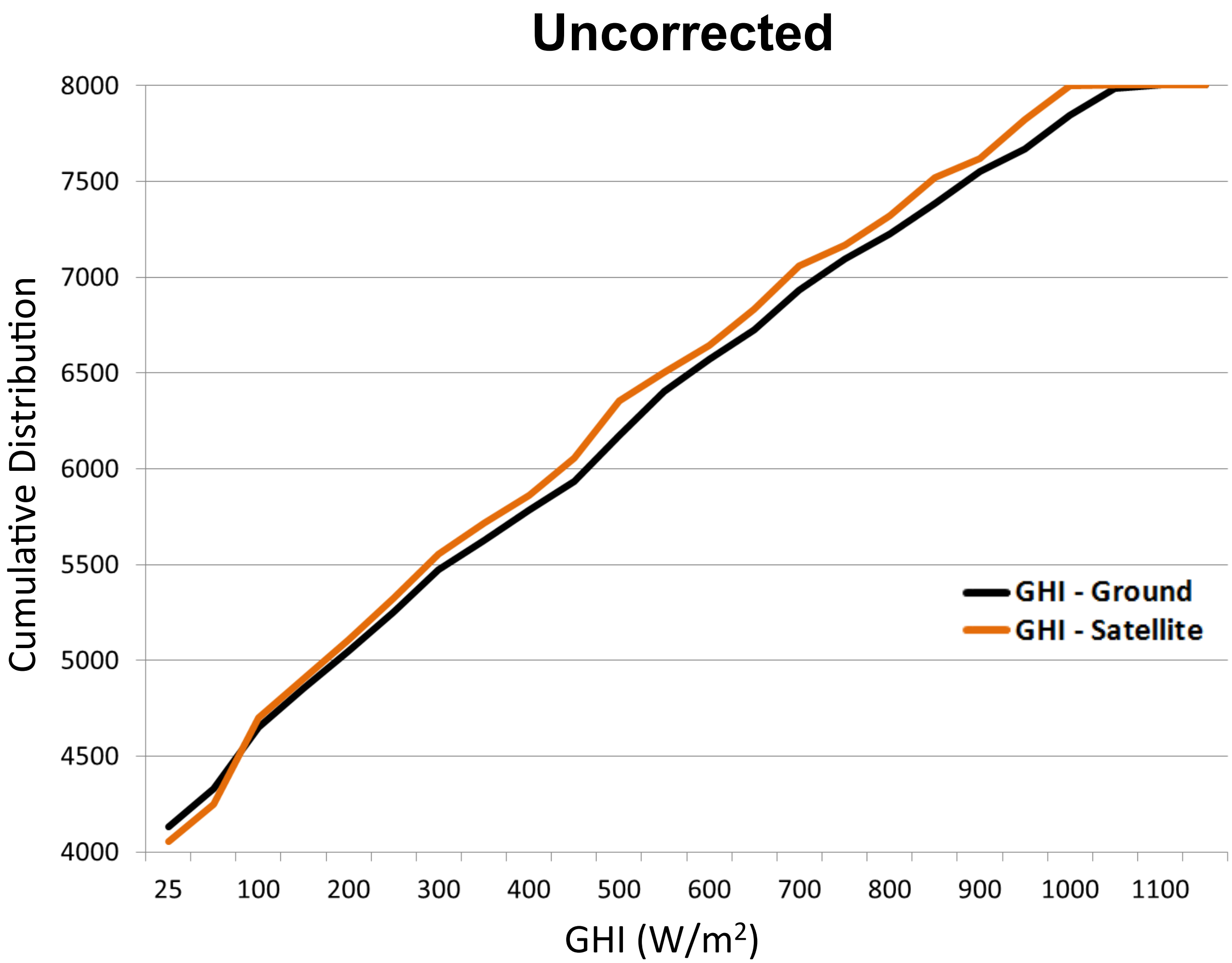
Tuning Satellite Data with Ground Observations: Cloud Measurement Error



Overall Bias: 4.6%
Clear Sky Bias: 4.1%

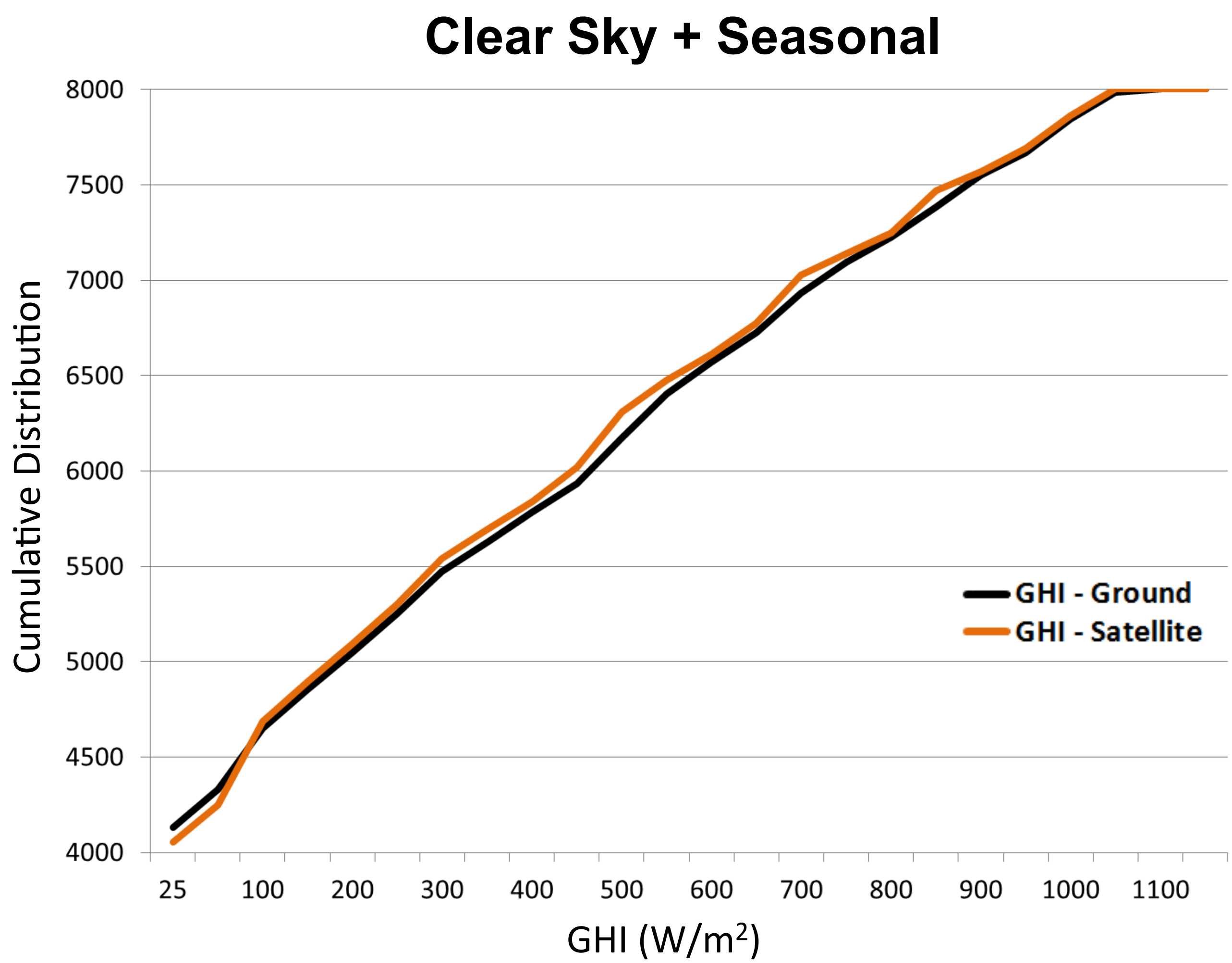
How do we target bias in the cloud measurements?

Tuning Satellite Data with Ground Observations: Cloud Measurement Error



Overall Goal: Minimize error (RMSE and KSI)

Tuning Satellite Data with Ground Observations: Cloud Measurement Error



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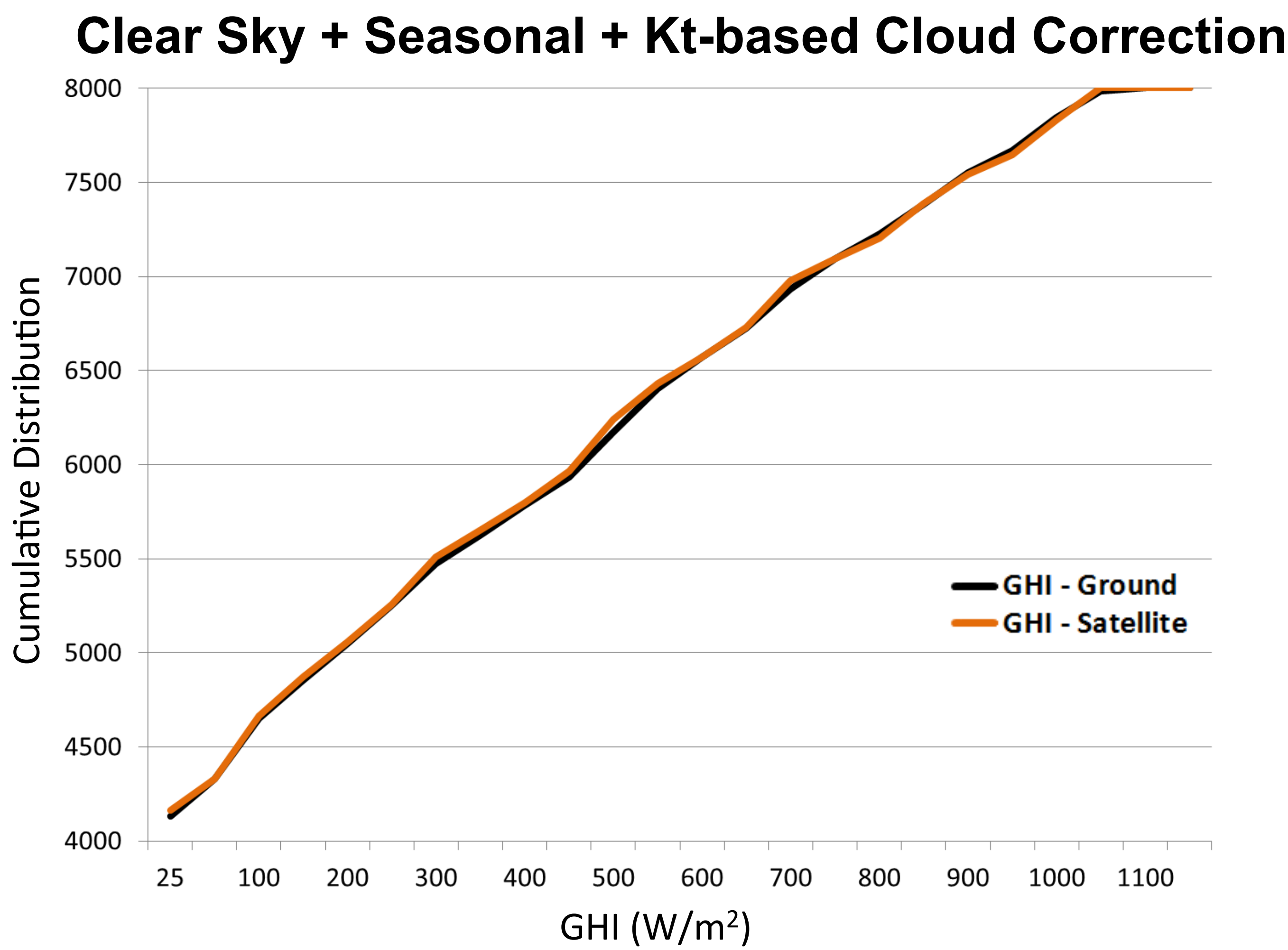
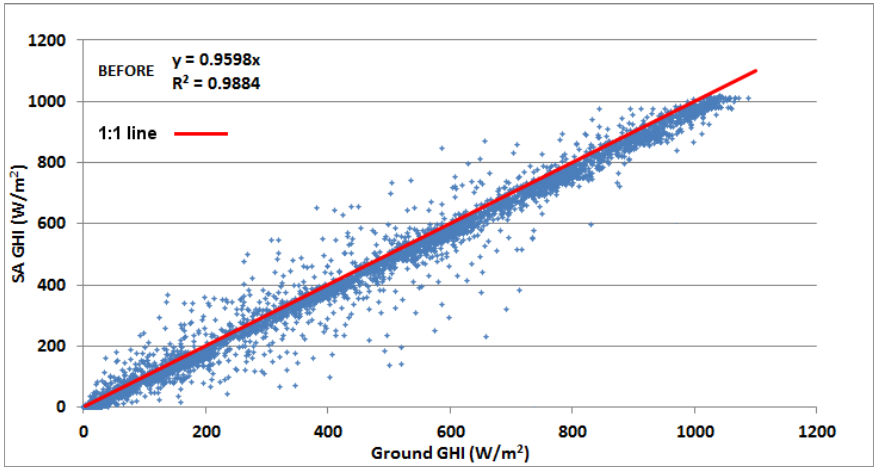
Tuning Satellite Data with Ground Observations: Cloud Measurement Error



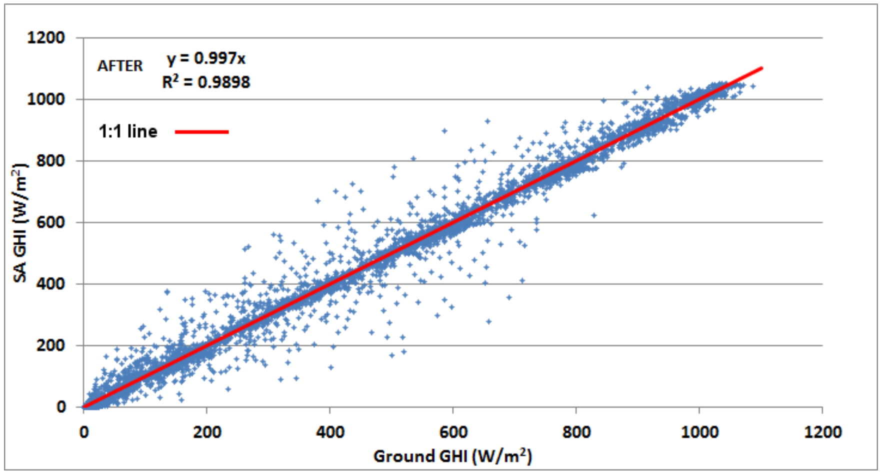
Overall Goal: Minimize error (RMSE and KSI)

Tuning Satellite Data with Ground Observations: Case Study Results

Ground/Satellite Tuning Results



Original Data

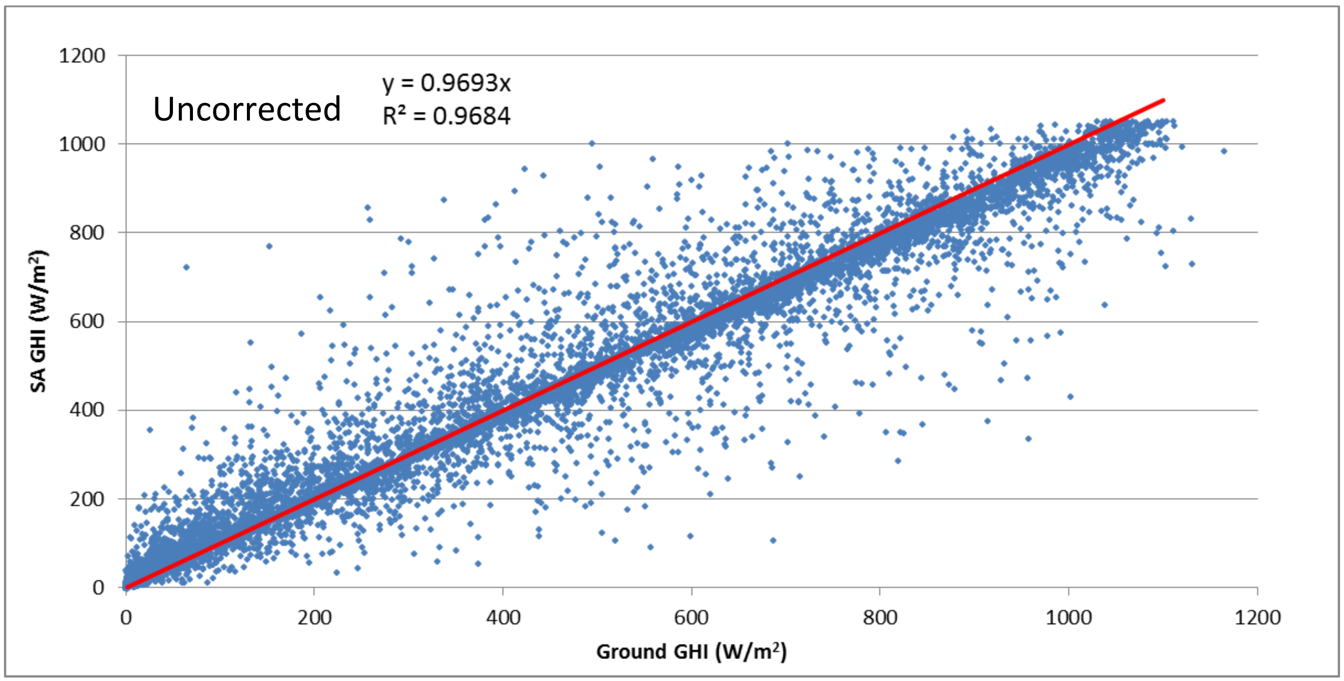


Final Tuned Data

Tuning Satellite Data with Ground Observations: Multi-year Validation

Two years of high quality ground data combined with SolarAnywhere ("SA") satellite data

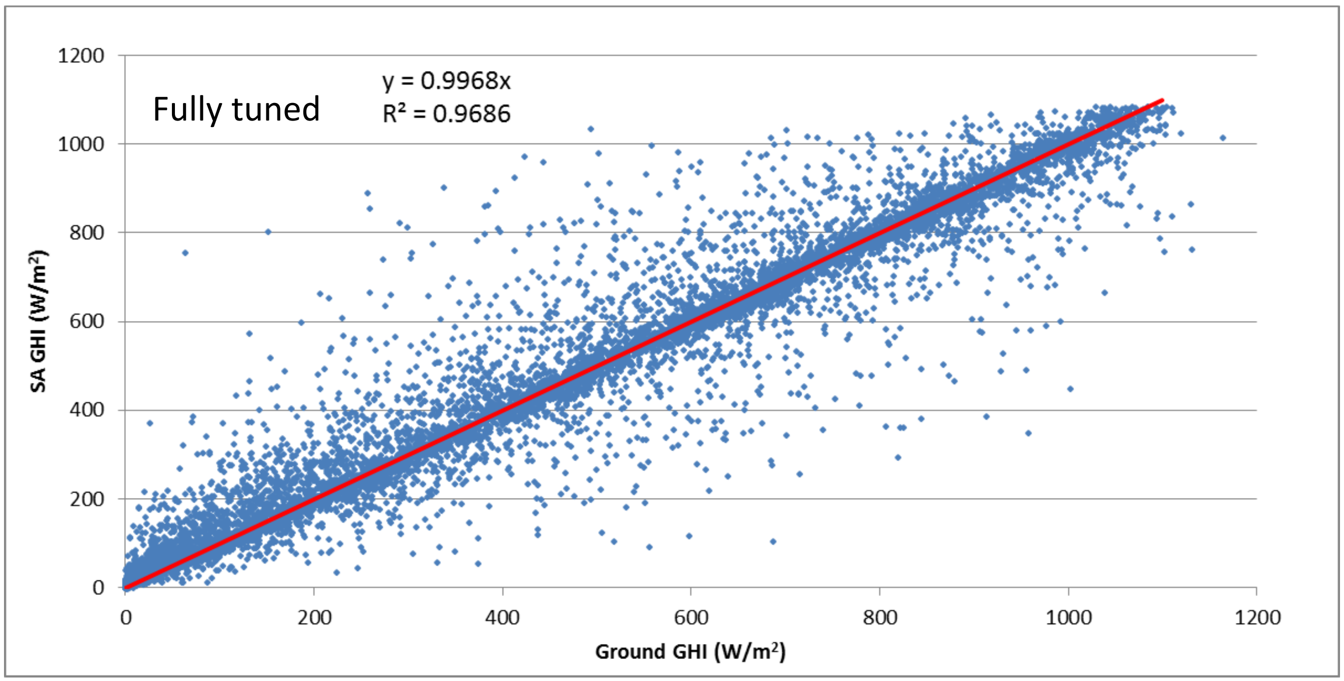
	Year 1 rMBE
Overall	-0.59%
Clear Sky	-2.71%



Tuning Satellite Data with Ground Observations: Multi-year Validation

Two years of high quality ground data combined with SolarAnywhere ("SA") satellite data

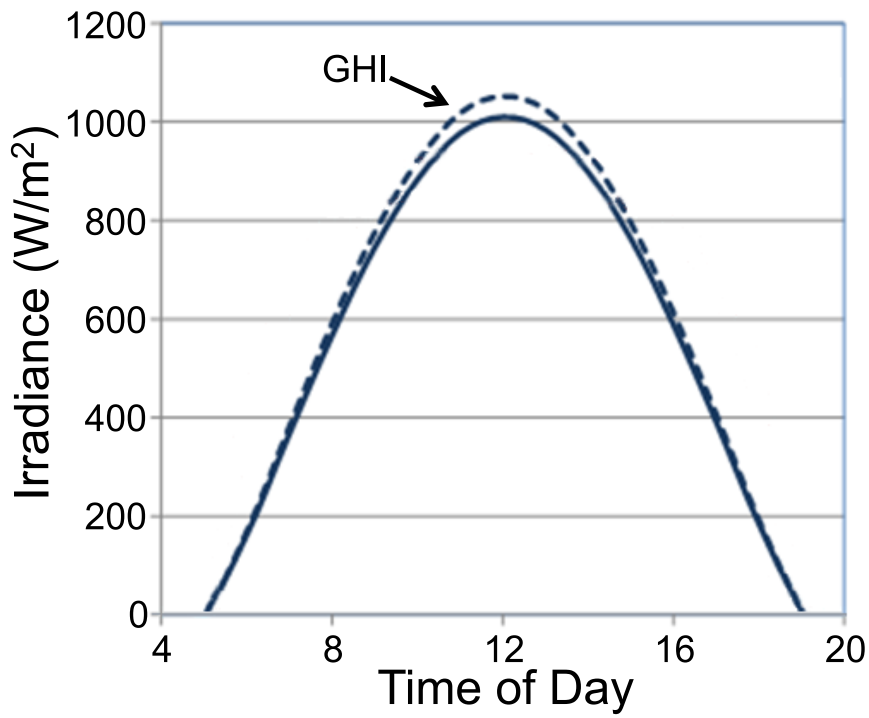
	Year 1 rMBE	Year 2 rMBE	Combined rMBE
Overall	-0.59%	-0.75%	-0.67%
Clear Sky	-2.71%	-3.16%	-2.93%



Targeted satellite tuning is reasonably consistent on a year-to-year basis

Other Considerations: Satellite DNI/DHI Rebalancing

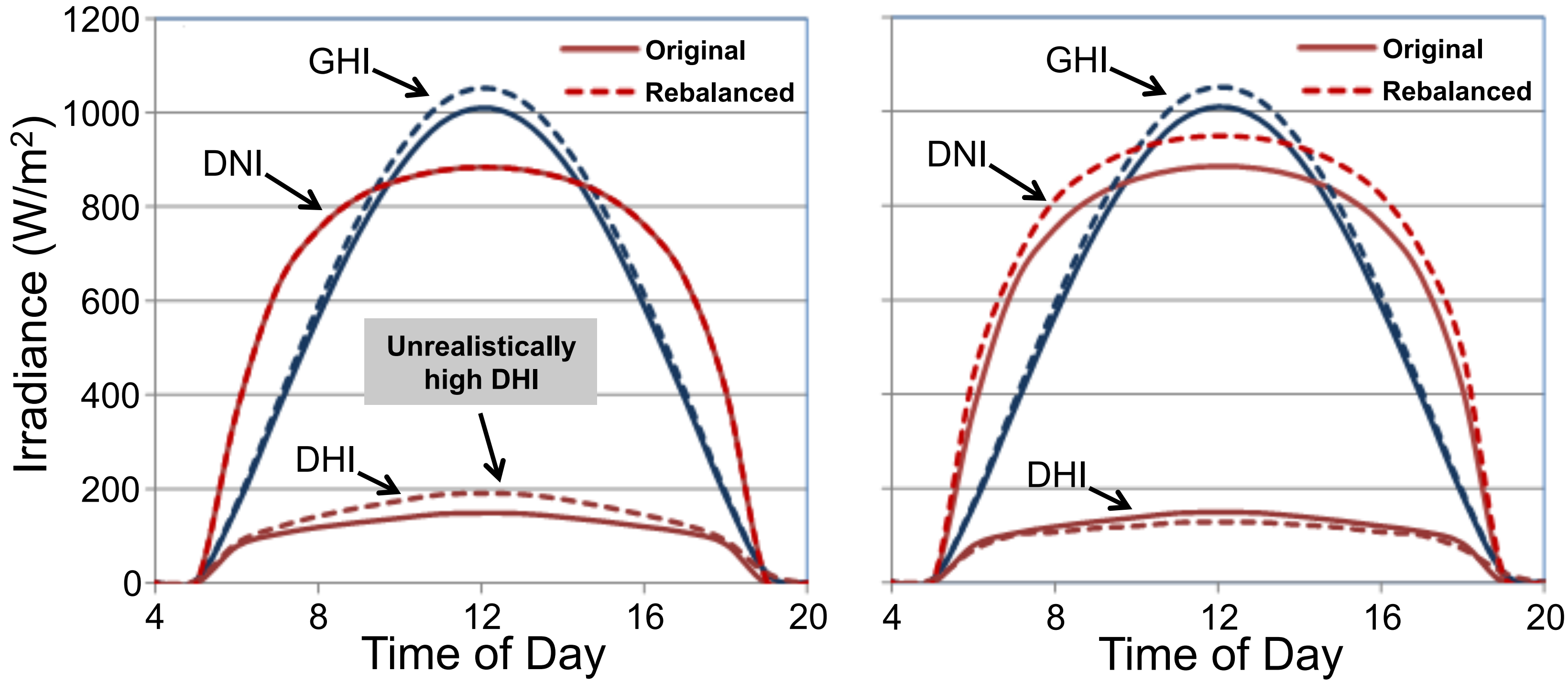
GHI = COS(Z)*DNI + DHI



Correction up in GHI needed due to modeled AOD inputs. What about DNI and DHI?

Other Considerations: Satellite DNI/DHI Rebalancing

GHI = COS(Z)*DNI + DHI



Improper rebalancing can skew PV energy simulations (PVsyst & SAM)

Simple corrections do not address clear/cloudy sky biases and DNI rebalancing needs

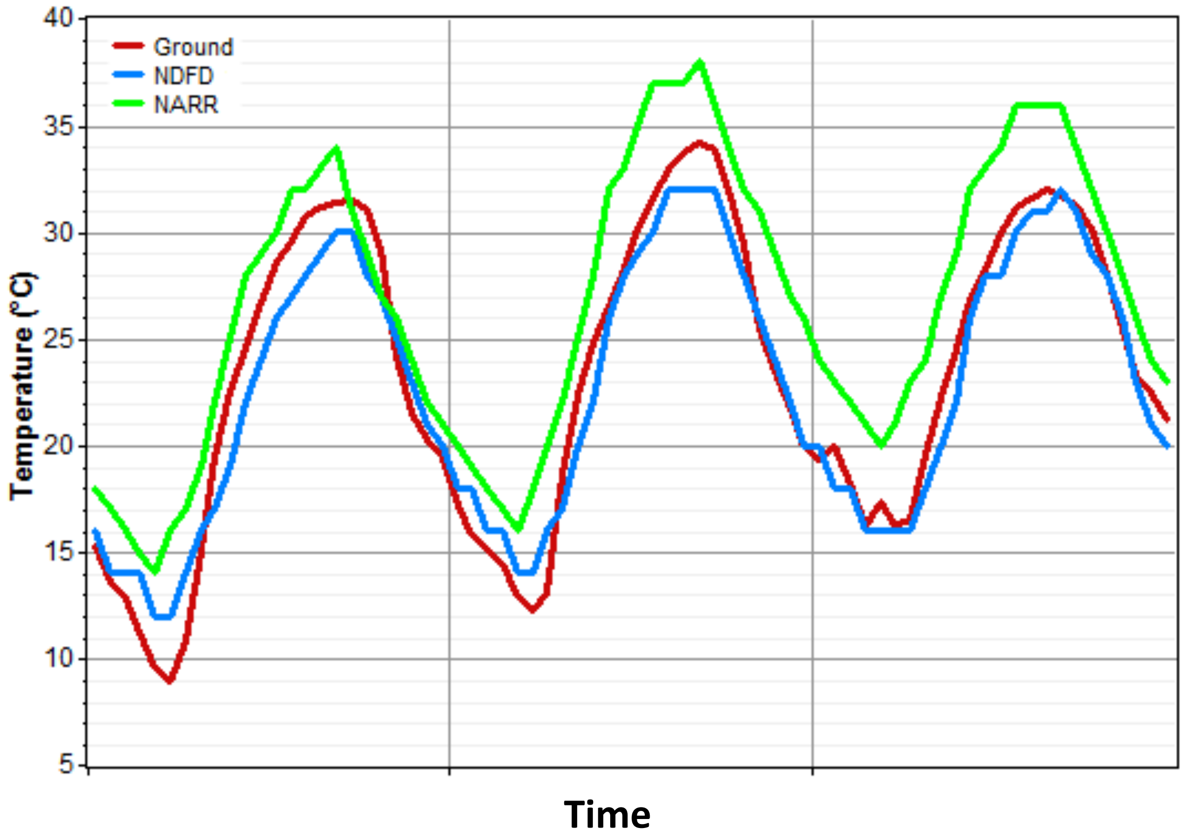
Other Considerations: Ancillary Meteorological Data Collection

Standard surface observations are taken at 2 meters for dry bulb temperature and 10 meters for wind speed and direction.

NWS ASOS weather station (image credit: NOAA)

Long term reference datasets (both observed and modeled) report 2 meter dry bulb temperature and 10 meter wind speed and direction data. PV site met observations taken at different levels will need to be reconciled with long term reference met sources

Other Considerations: Ancillary Meteorological Data Biases



Site Air Temperature Biases

NDFD (all)	NDFD (day)	NARR (all)	NARR (day)
0°C	-0.8°C	+2.9°C	+2.6°C

Need to correct for daytime-only biases in long term ancillary datasets

A +2°C swing in temperature results in a -1% swing in energy output in PVsyst for most PV modules

Conclusion: Ground + Satellite Data
"Better together when properly combined"

Run a well maintained and monitored ground campaign and collect 1+ year of high-quality ground data

Combine in ligently with long-term reference sate e and ancillary met data

=

Results in lowest uncertainty and most reliable solar resource available for a solar project site

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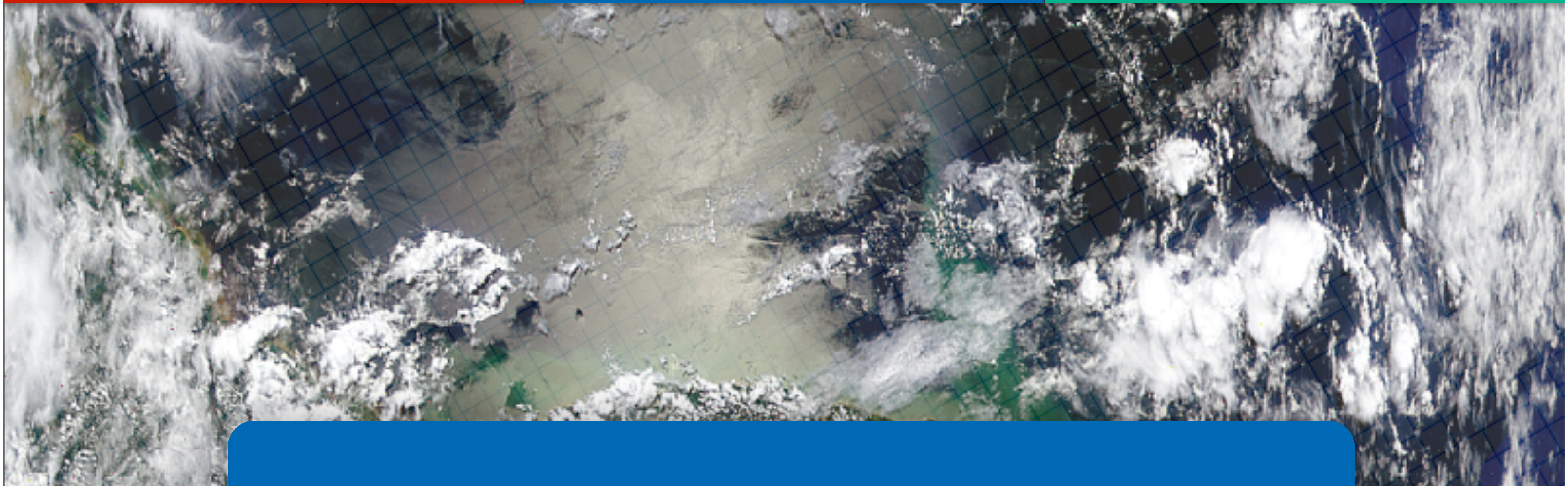

Thank you

Please feel free to contact us for any details or clarification related to presentation

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