

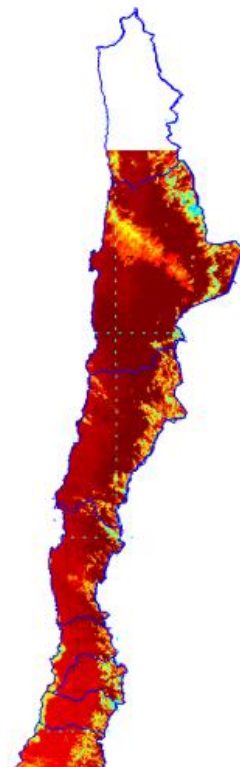
# Resource Assessment Activities at UC

Rodrigo Escobar

Centro de Energía - Escuela de Ingeniería

Pontificia Universidad Católica de Chile

[rescobar@ing.puc.cl](mailto:rescobar@ing.puc.cl)





# Field Measurements

RE, Apino, Ccortés, Aortega,  
JMCardemil, Msalgado

1. Produce quality data for validation of satellite products
2. Support industry in PV and CSP projects
3. Analyze differences in irradiance time series for different climates in Chile



La Tirana, Tarapacá.  
DICTUC / Latin America Power



Alto Patache, Tarapacá.  
Centro UC Desierto de Atacama

Alta corrosión: humedad y salinidad.



Carrera Pinto, Illa región.  
Solar Reserve

# Measurement network

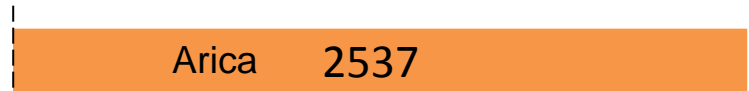


Nombre	Localización	Altitud	Región	Tipo de estación	Período de operación	
Arica	Lat: 18,48° S Lon: 69,92° W	1.792 m.s.n.m.	XV región de Arica y Parinacota	RSBR	01/08/2011 - a la fecha	
Pozo Almonte	Lat: 20,26° S Lon: 69,77° W	1030 m.s.n.m.	I región de Tarapacá	RSBR	04/04/2012 - a la fecha	
Patache	Lat: 20,83° S Lon: 70,16° W	760 m.s.n.m.	I región de Tarapacá	RSBR	16/01/2013 - a la fecha	
Sur Viejo	Lat: 20,94° S Lon: 69,54° W	930 m.s.n.m.	I región de Tarapacá	RSBR	07/07/2011 - a la fecha	
Crucero	Lat: 22,24° S Lon: 69,51° W	1.146 m.s.n.m.	II región de Antofagasta	RSBR	16/01/2012 - a la fecha	
Coya Sur	Lat: 22,40° S Lon: 69,63° W	1.320 m.s.n.m.	II región de Antofagasta	RSBR	05/07/2011 - a la fecha	
San Pedro de Atacama	Lat: 22,91° S Lon: 68,20° W	2.450 m.s.n.m.	II región de Antofagasta	Estación completa	03/12/2010 - 04/07/2011	

Not shown: Carrera Pinto (RSR), Jucosol (Solys 2)  
Santiago: RSR, Solys 2 (UC); Solys 2 (UChile).

# Yearly total measured irradiation

GHI  
kWh/m<sup>2</sup>



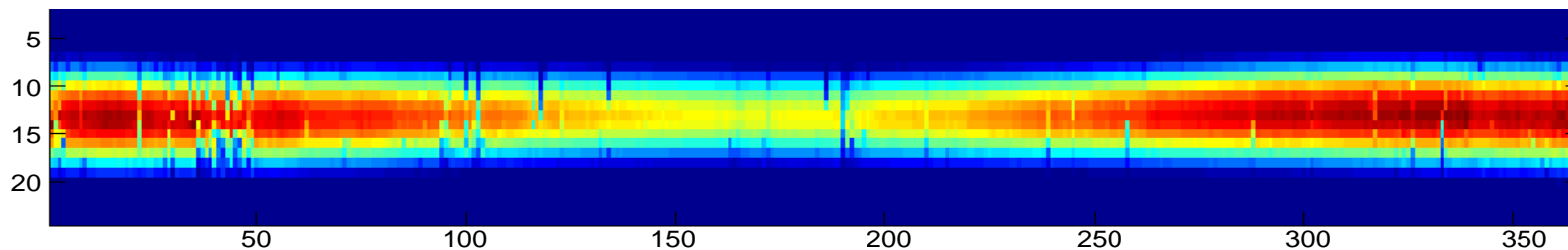
DNI ~ 3500 kWh/m<sup>2</sup>  
for Atacama sites



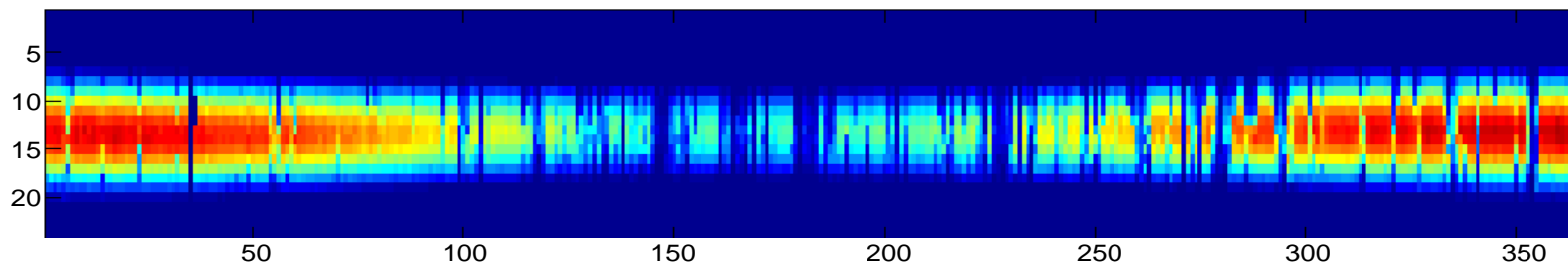


# Annual cycle

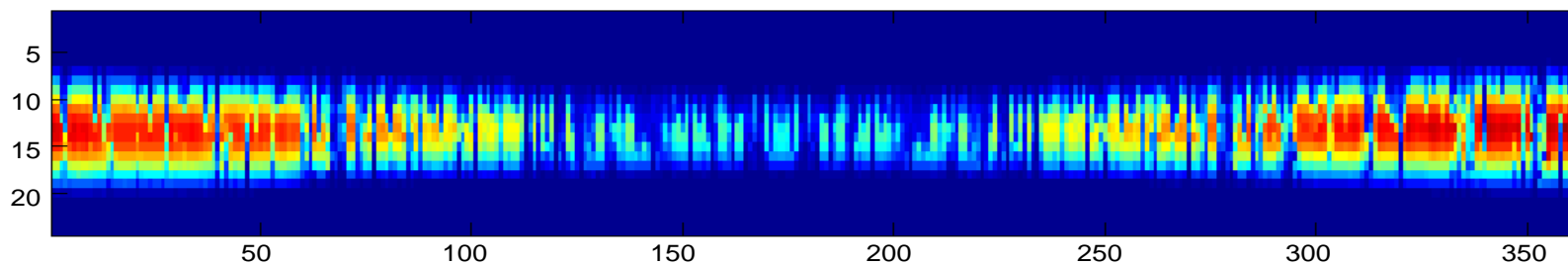
Hora del día



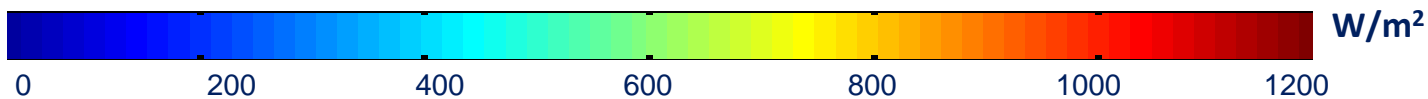
Coya Sur



Santiago



Curicó







Clouds in the  
Atacama

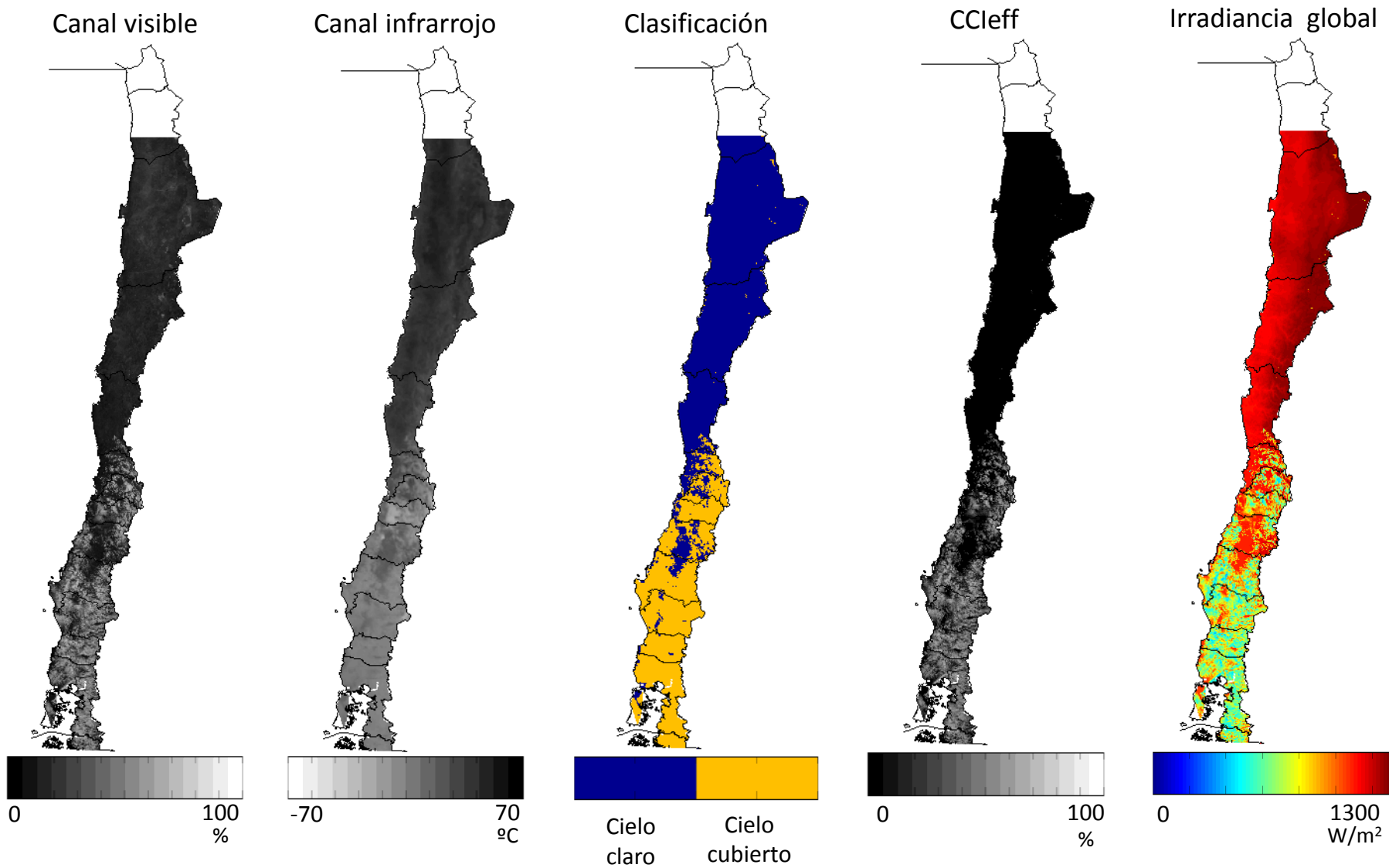


# Satellite Estimation

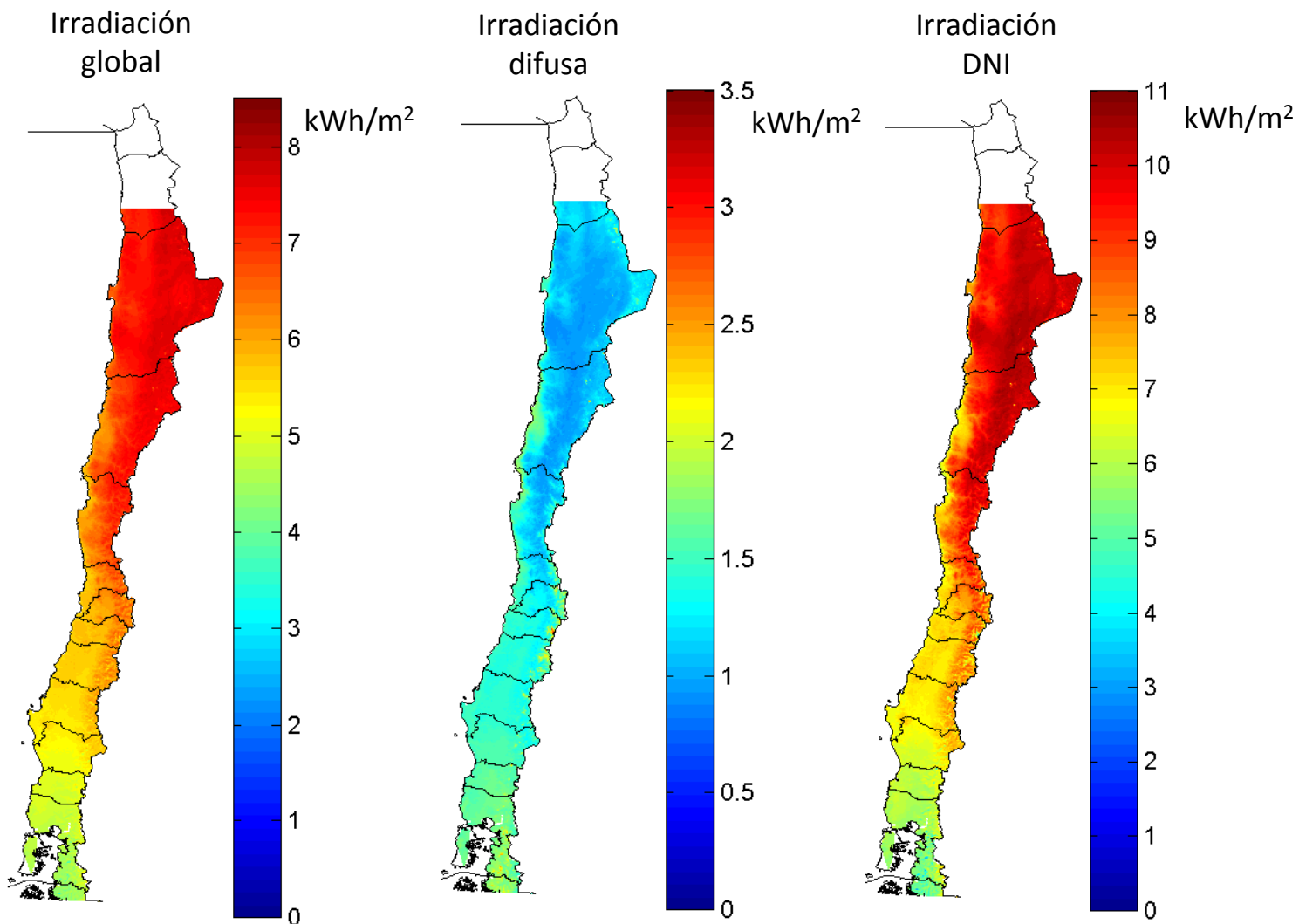
RE, Apino, Ccortés, Aortega

1. Fill a knowledge gap for irradiance data in Chile (2008-2013)
2. Establish (detect) needs for local adaptation of existing methodologies to particular conditions in Chile

# Simplified Methodology

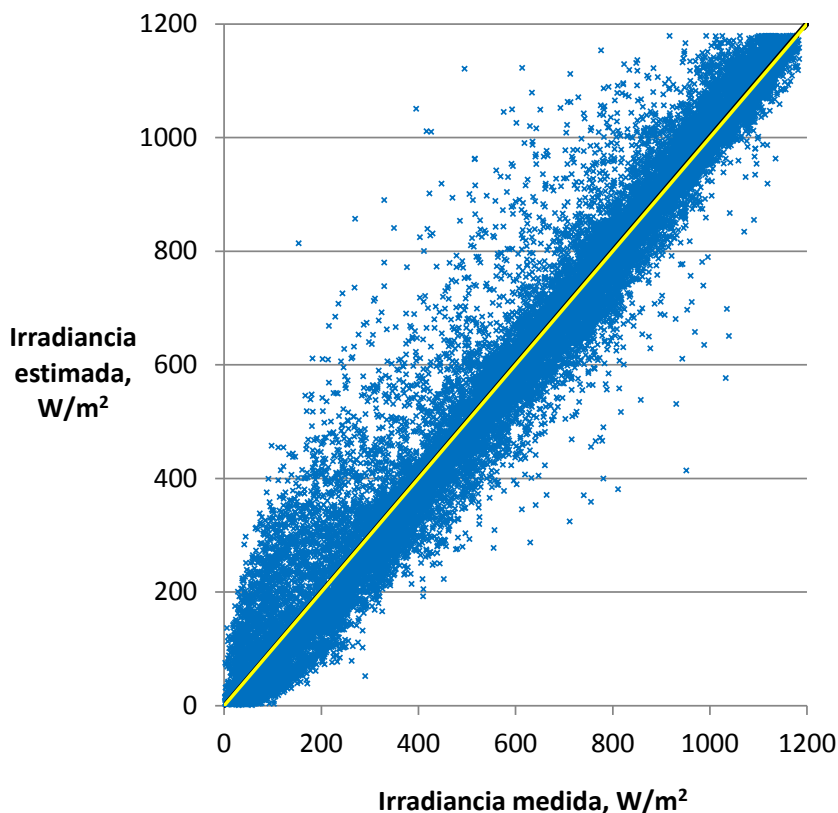


# Results: Yearly Average

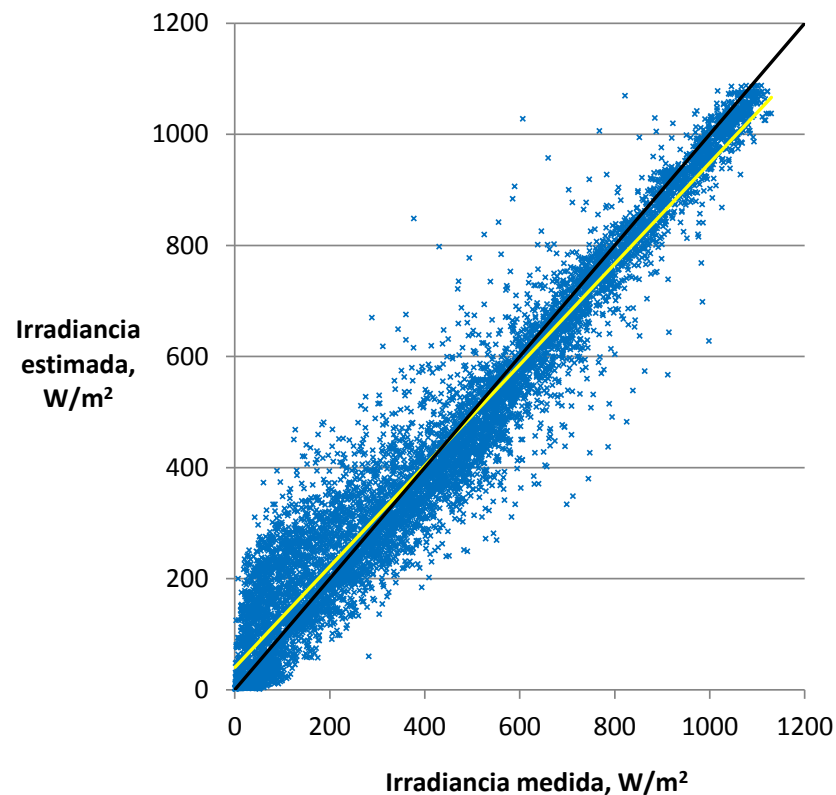


# Validation Ground vs. Estimated Irradiance

**Atacama desert**



**Central Chile**



**Daily irradiation**

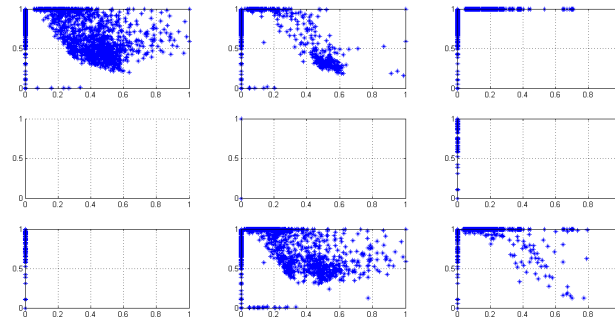
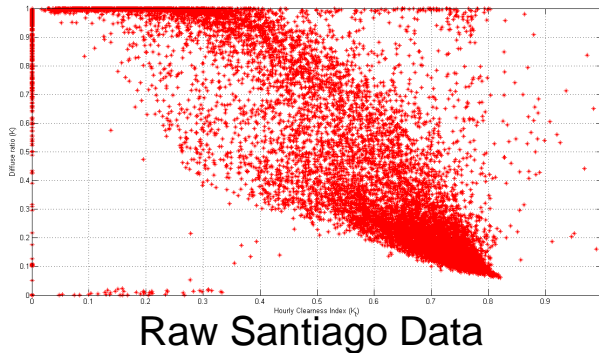
MBE, kWh/m <sup>2</sup>	rMBE, %	RMSE, kWh/m <sup>2</sup>	rRMSE, %
-0,13	-2,1	0,57	8,9



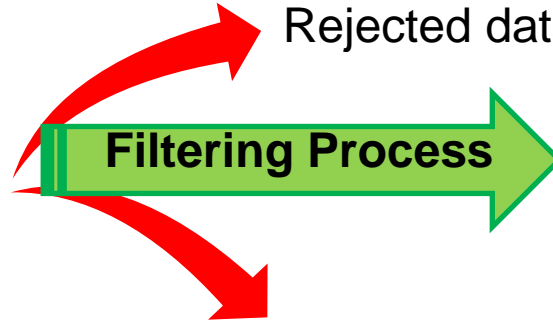
# Diffuse Fraction and Artificial DNI Series

Rgarcía, RE

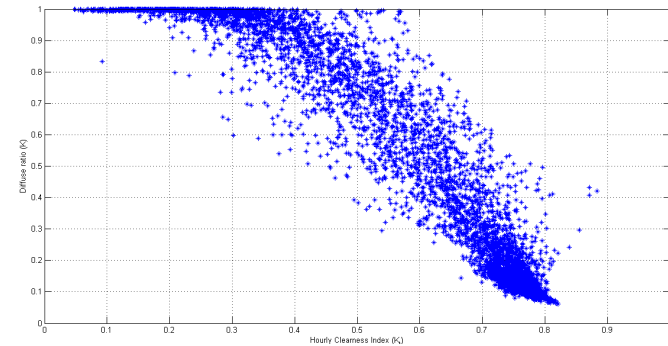
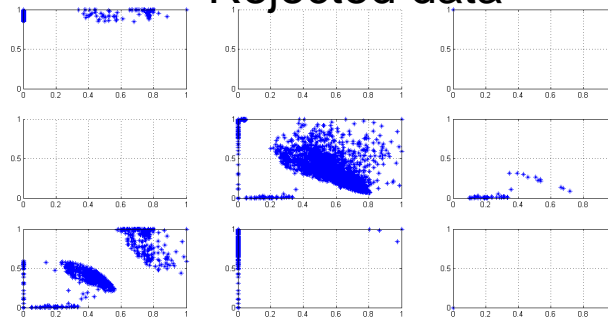
1. Generate acceptable DNI data for several stations that only measure GHI
2. Adapt diffuse fraction models to several climate systems in Chile (13)



Rejected data



Rejected data



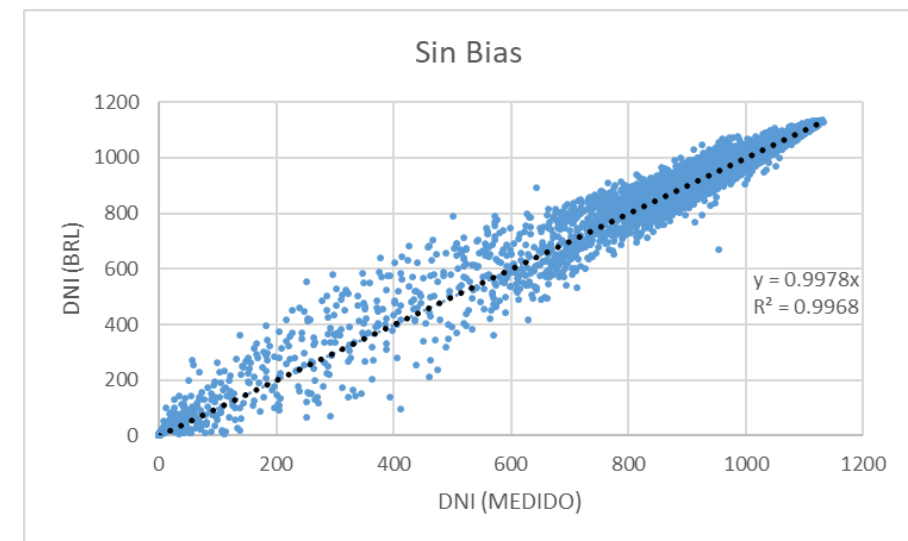
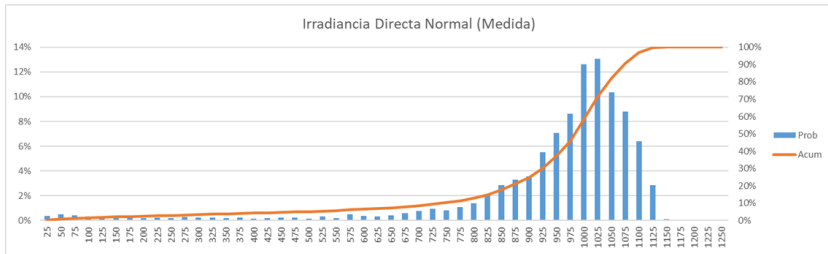
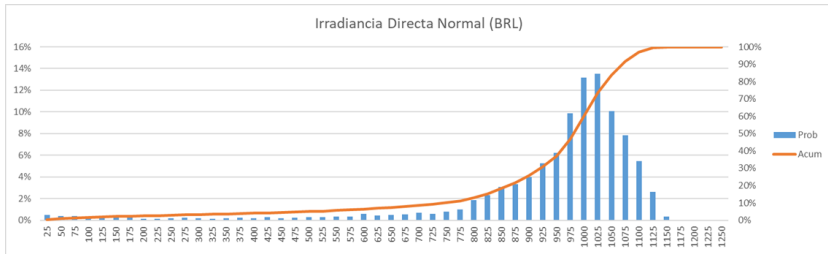
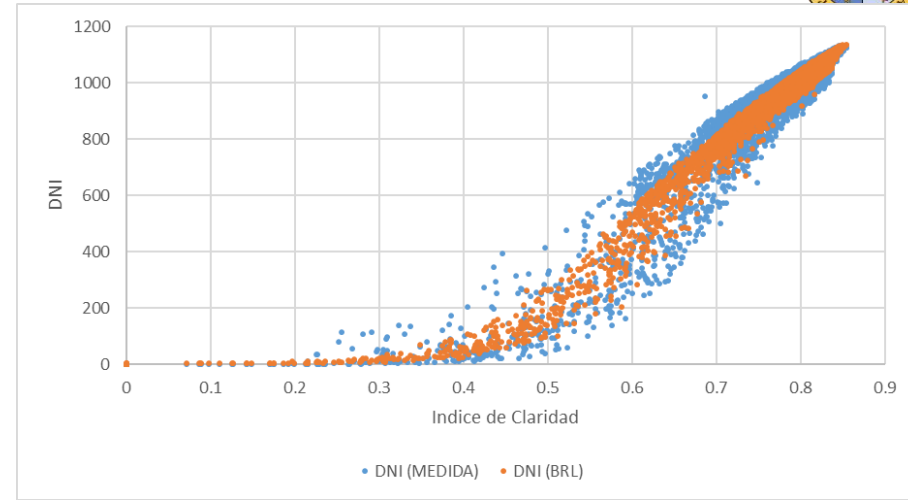
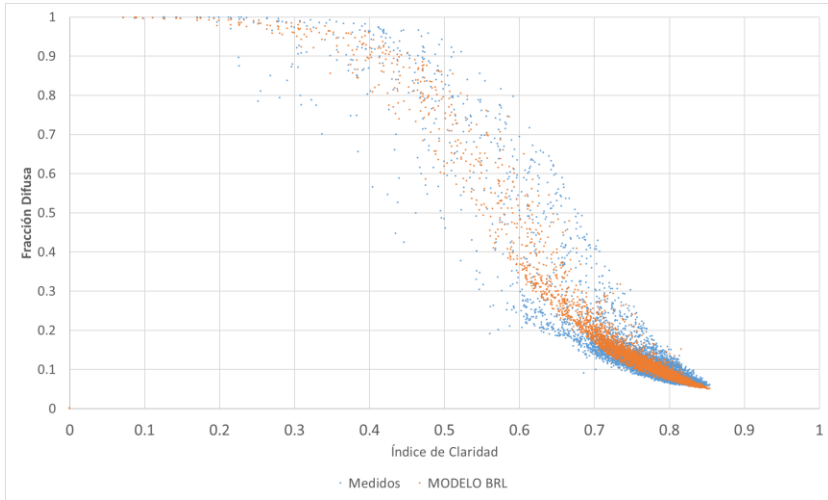
Filtered Santiago Data

Several pyranometer-only measurement stations.

BRL model applied to measured GHI to obtain diffuse fraction.

DNI is estimated from BRL diffuse fraction and used to create artificial time-series.

# Carrera Pinto



Artificial DNI series: acceptable KSI and RMSE

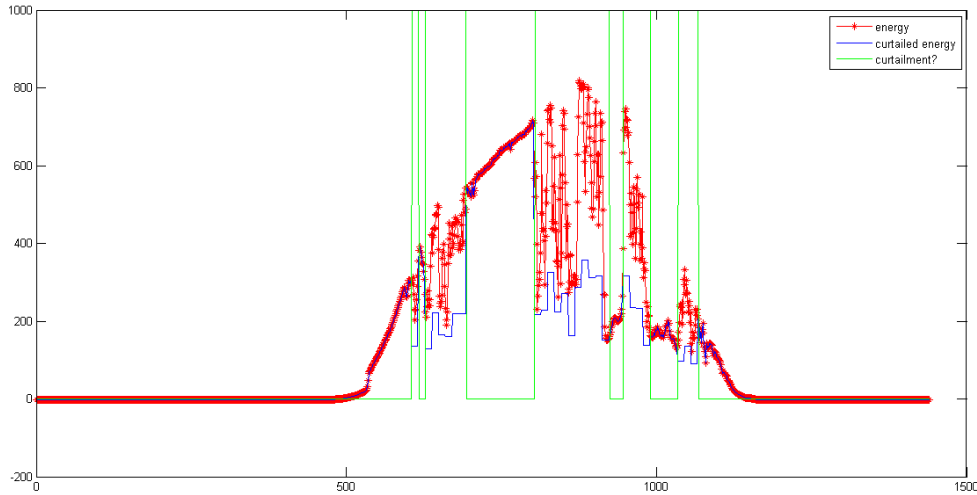




# Economic value of Forecasting

IPérez, Acastillejo, RE

1. Determine economic value of forecasting in Chile → correlate avoided curtailment losses with forecasting accuracy
2. Analyze and characterize irradiance variability in the Atacama → higher than anticipated
3. Support large-scale penetration of PV to Chilean Grid → next step DNI for CSP

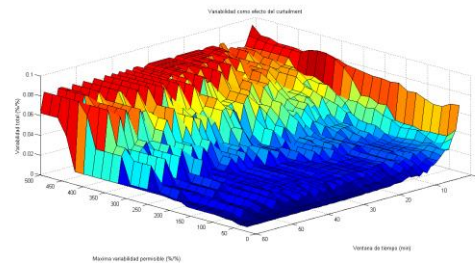
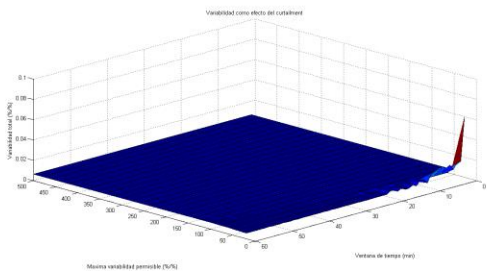
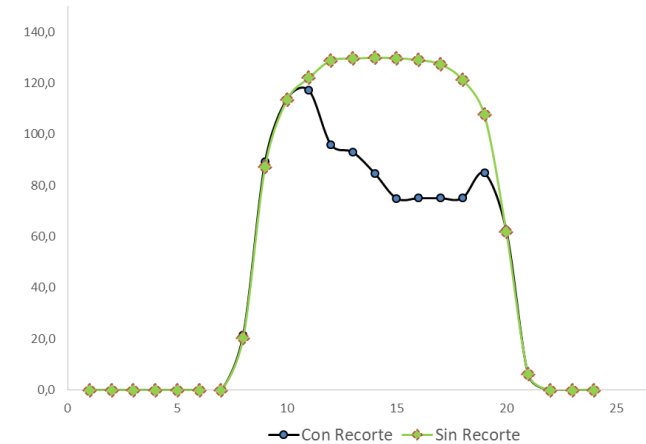
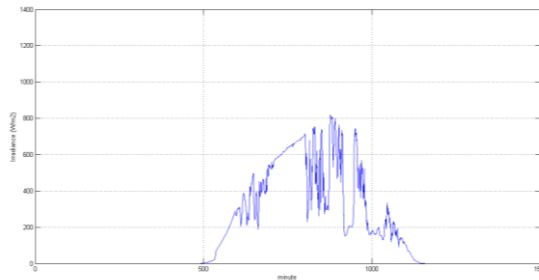
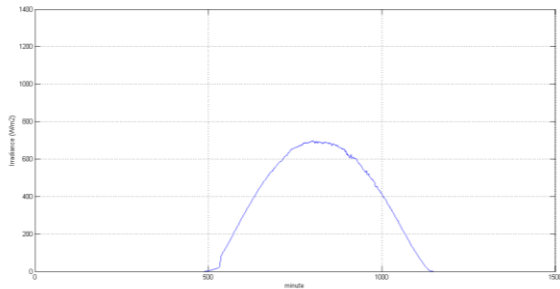


$$\text{Energy Difference} = \frac{\int (G_{\text{actual}} - G_{\text{curtailed}}) dt}{\int G_{\text{actual}} dt}$$

$$\text{Cost Difference} = \frac{\int (G_{\text{actual}} - G_{\text{curtailed}}) dt}{\int G_{\text{actual}} dt} * \text{Energy price}$$

$$\text{Plant Variability} = \frac{\int \left| \frac{dG_{\text{curtailed}}}{dt} \right| dt}{\int G_{\text{actual}} dt}$$

$$\text{curtailment} = \begin{cases} 0, & x < \text{maximum allowed variability} \\ 1, & x \geq \text{maximum allowed variability} \end{cases}$$





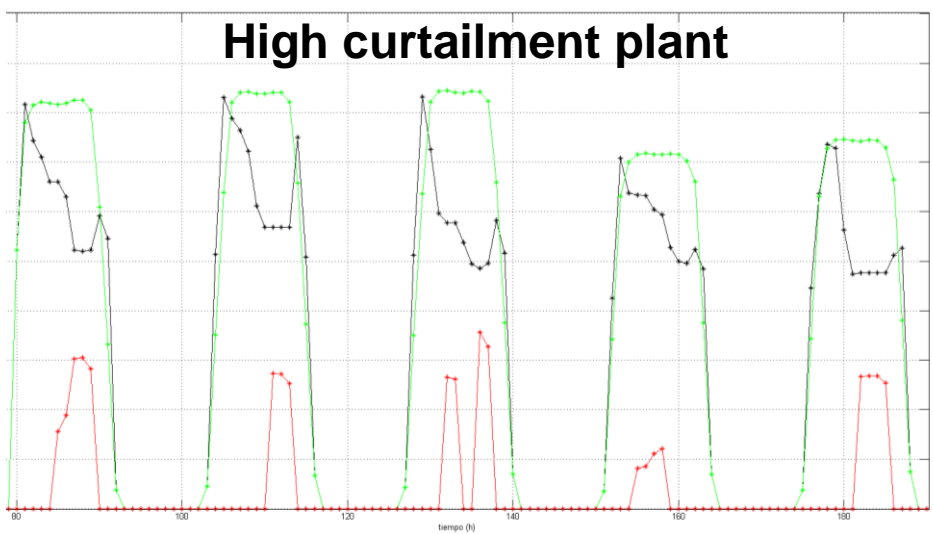
# Curtailment Estimation



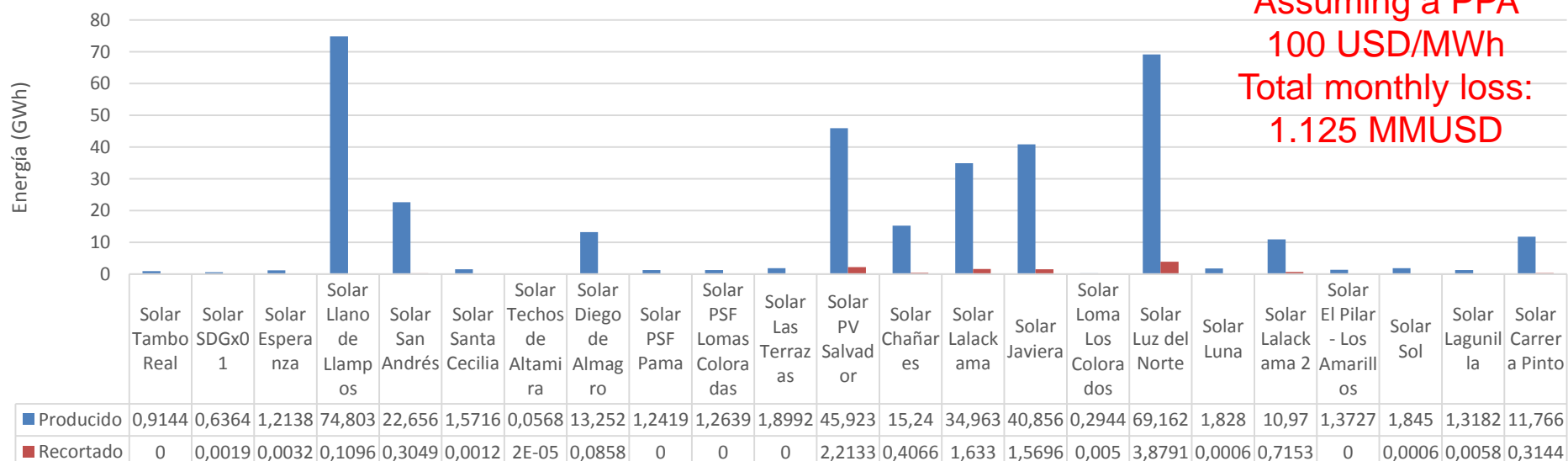
### Low curtailment plant



### High curtailment plant



### Producción solar PV y recorte en plantas SIC



Assuming a PPA  
100 USD/MWh  
Total monthly loss:  
1.125 MMUSD

# AOD effects on Irradiance and PV production

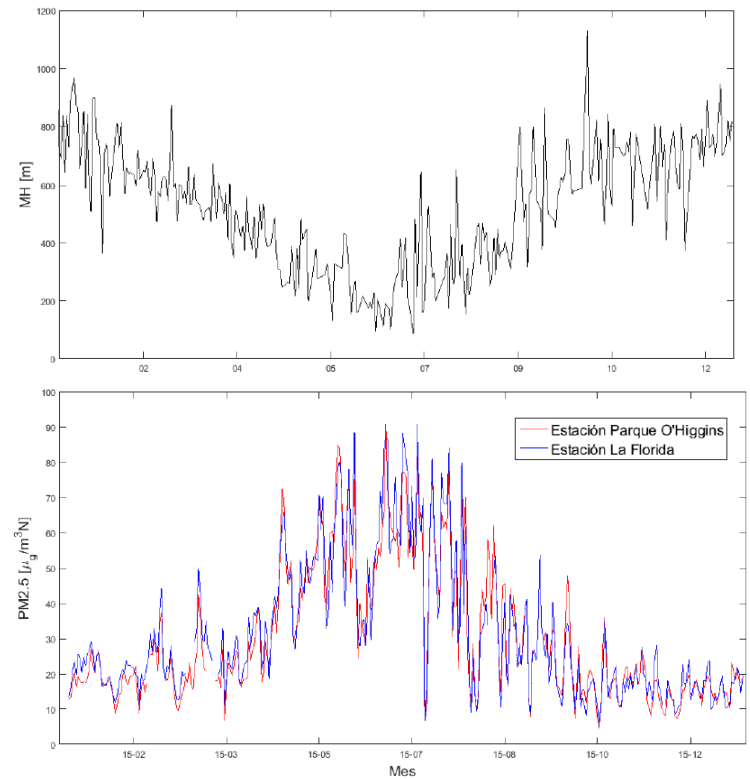
MDelHoyo\*, Rrondanelli\*, RE

\*: Universidad de Chile, FCFM, Geofísica

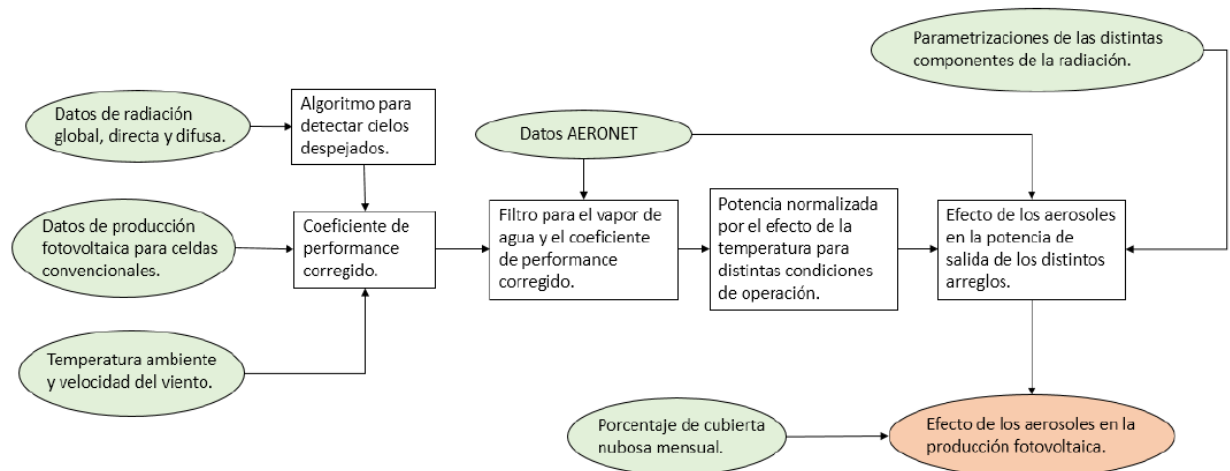
1. Understand effect of local aerosols (pollution/natural): irradiance and PV production
2. Develop a predictive tool for CPV simulations



- Severe pollution episodes during Winter in Santiago.
- Effect of aerosols on irradiance and PV production?
- Enough to merit special technology selection?



- AOD-based model for Irradiance and PV production
- Validated with ground measurements



# UC Solar Lab

3 technologies: m-Si, p-Si, a-Si  
~8 kW

Resource  
assessment  
and PV testing



Figura 3.1: Ubicación y foto en la terraza de Geofísica de la Universidad de Chile del fotómetro CIMEL.

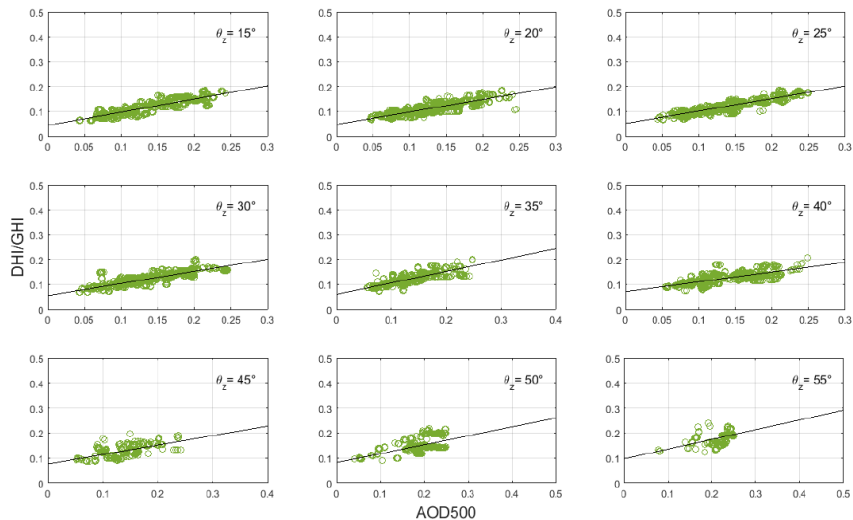


Figura 4.4: AOD versus fracción de radiación difusa sobre global en Santiago para nueve ángulos distintos.

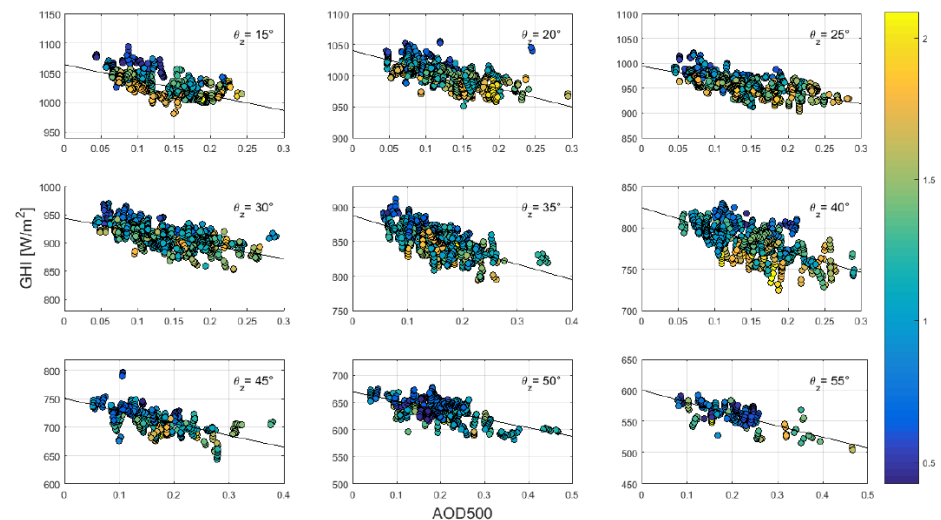
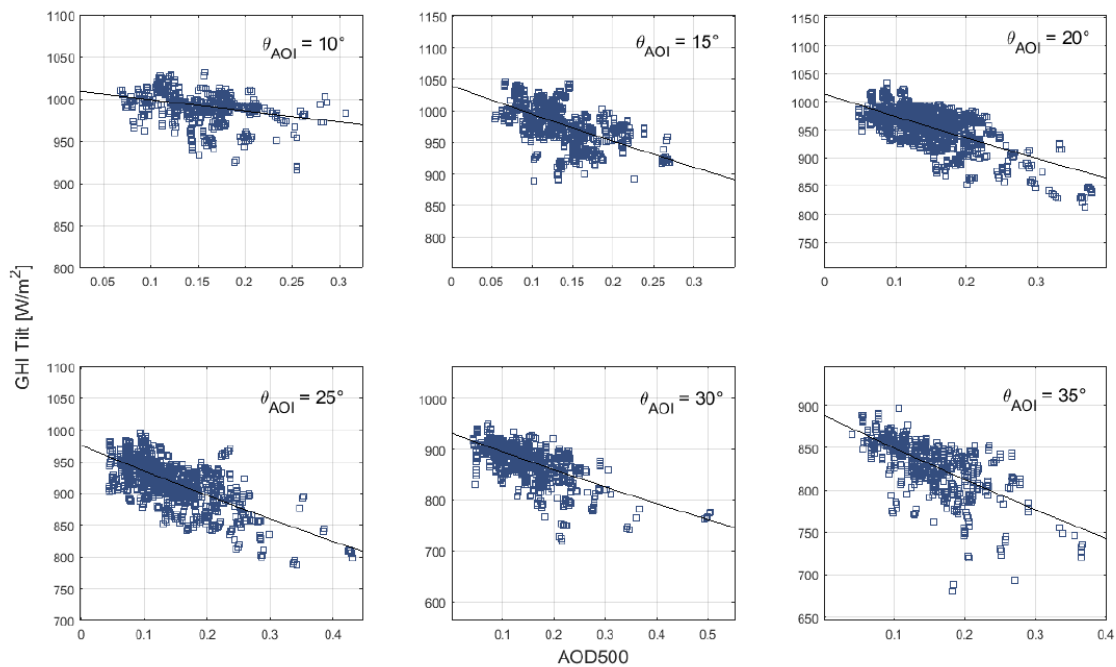


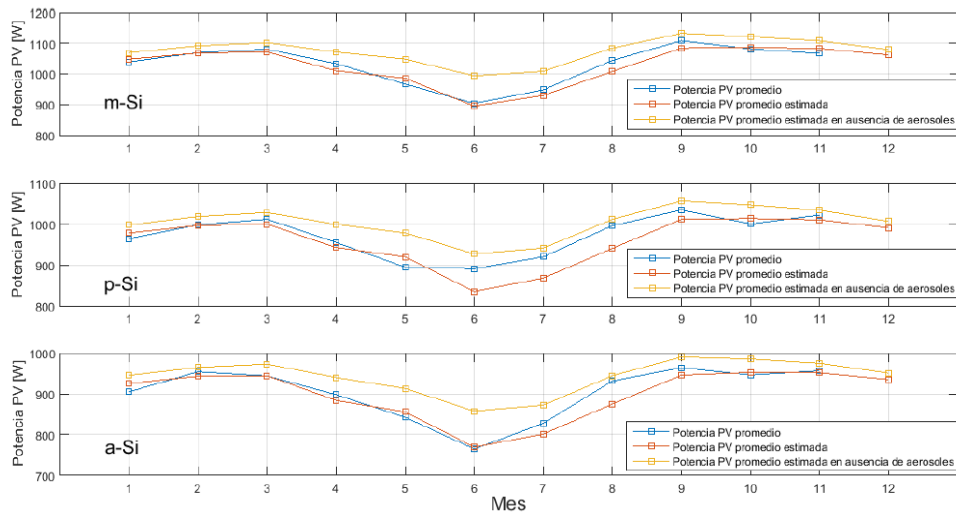
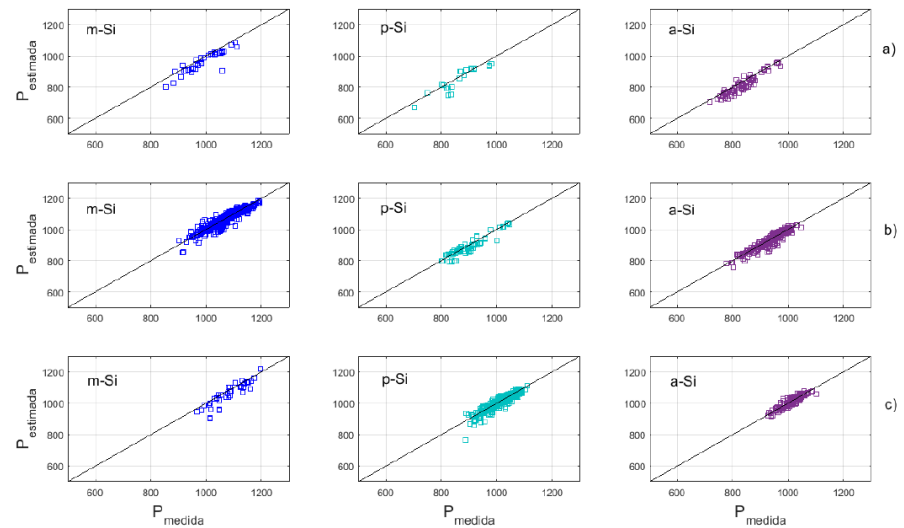
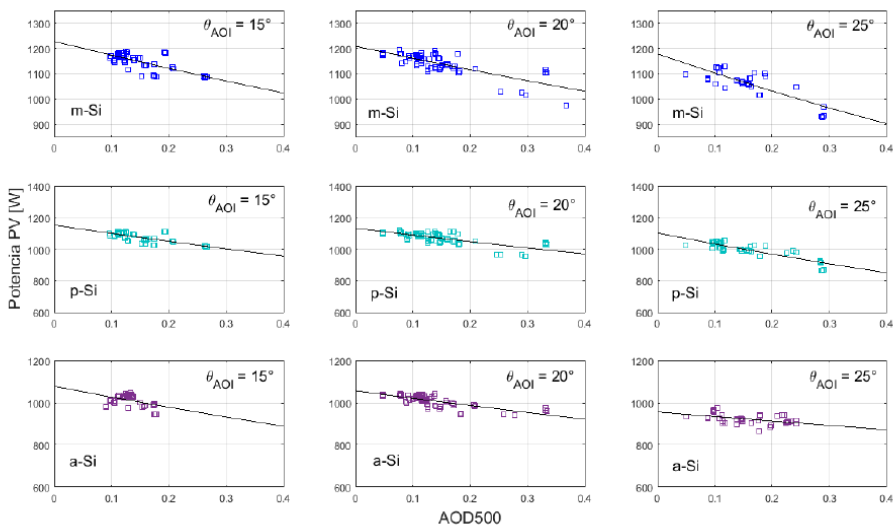
Figura 4.5: AOD versus fracción de radiación difusa sobre directa en Santiago para nueve distintos ángulos. La barra de colores representa la cantidad de vapor de agua en la columna en cm.

$$GHI = A \cdot \exp(B \cdot AOD)$$

$$DNI = A \cdot \exp(B \cdot AOD)$$

$$DNI = A \cdot AOD^B$$





Mes	Producción PV con los datos obtenidos [kWh]			Producción PV para un caso sin aerosoles [kWh]			% de pérdida		
	m-Si	p-Si	a-Si	m-Si	p-Si	a-Si	m-Si	p-Si	a-Si
Enero	102,71	95,28	89,42	105,68	98,62	93,41	-2,8 %	-3,4 %	-4,3 %
Febrero	95,05	88,76	84,80	97,02	90,53	85,75	-2,0 %	-2,0 %	-1,1 %
Marzo	95,71	89,64	83,59	97,62	91,09	86,18	-2,0 %	-1,6 %	-3,0 %
Abril	80,30	74,20	69,76	83,21	77,65	73,01	-3,5 %	-4,4 %	-4,5 %
Mayo	61,43	56,84	53,53	66,61	62,16	58,01	-7,8 %	-8,6 %	-7,7 %
Junio	51,82	51,08	43,87	56,99	53,18	49,20	-9,1 %	-3,9 %	-10,8 %
Julio	41,09	39,87	35,87	43,71	40,79	37,80	-6,0 %	-2,3 %	-5,1 %
Agosto	54,11	51,64	48,27	56,19	52,43	48,94	-3,7 %	1,5 %	-1,4 %
Septiembre	52,87	49,35	45,99	54,03	50,42	47,23	-2,1 %	-2,1 %	-2,6 %
Octubre	75,34	69,72	65,91	78,17	72,94	68,64	-3,6 %	-4,4 %	-4,0 %
Noviembre	86,95	83,32	77,97	90,33	84,29	79,46	-3,7 %	-1,2 %	-1,9 %
Diciembre	-	-	-	95,67	89,28	84,30	-	-	-
Anual	797,4	749,7	699,0	829,6	774,1	727,6	-3,88 %	-3,15 %	-3,94 %



# Resource Assessment Activities at UC

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rescobar@ing.puc.cl

