

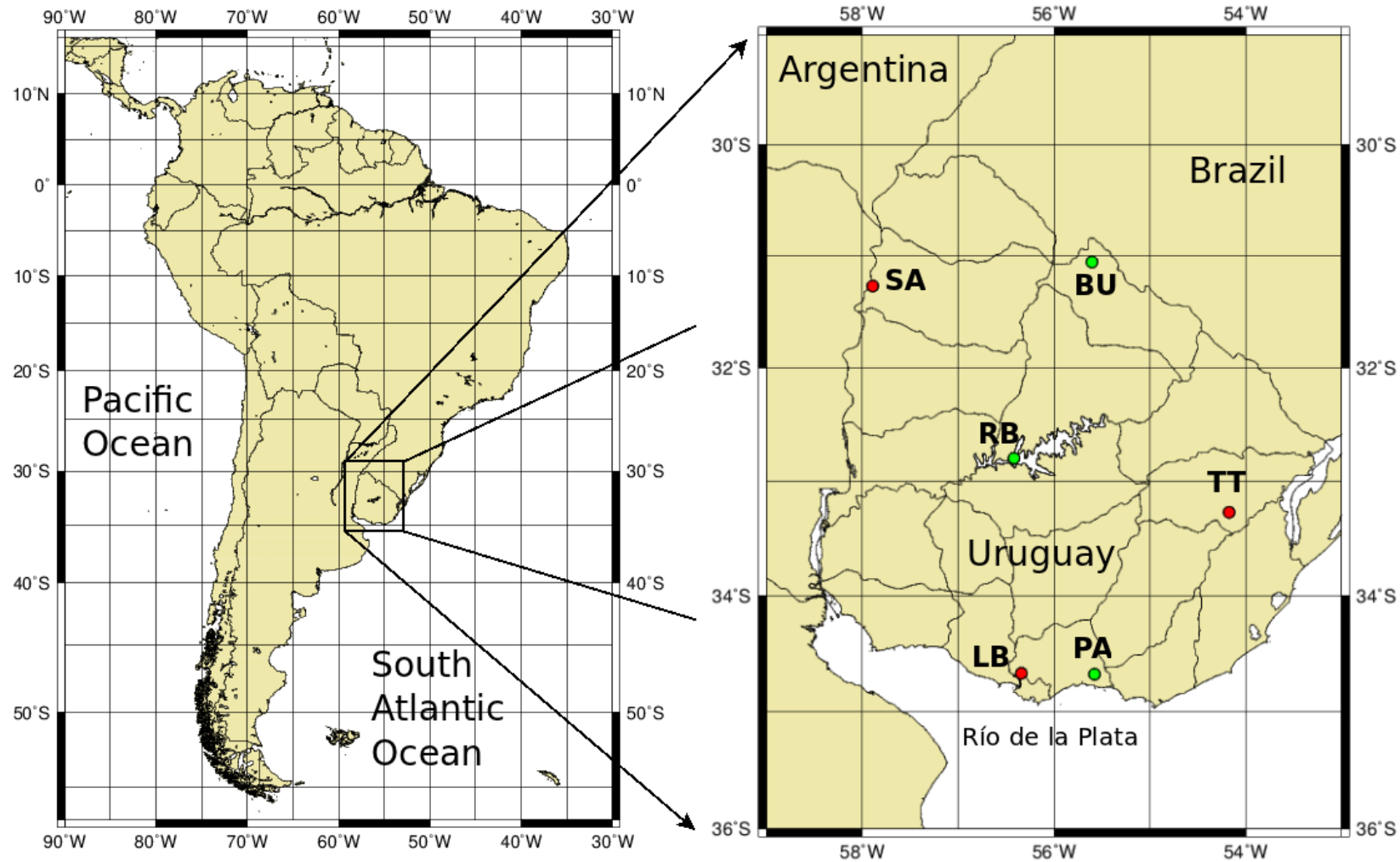
Solar Irradiation assessment in Uruguay using Tarpley's model and GOES Satellite images

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target territory: Uruguay, South America



Tarpley's model

[JPT 1986]

$$I = I_{sc} (r_0/r)^2 (a \cos \theta_z + b \cos^2 \theta_z + c \cos^3 \theta_z) + d (B_m^2 - B_0^2)$$

with:

I: global hourly irradiation at ground level on a horizontal surface

$I_{sc} = 4.921 \text{ MJ/m}^2$: hourly integrated solar constant

r_0/r : eccentricity factor (depends on the Julian day, n)

θ_z solar zenith angle (depends on n , local time and position)

B_0 : clear day brightness counts (depends on $\cos \theta_z$)

B_m : mean brightness counts (depends on time and position)

cloudiness

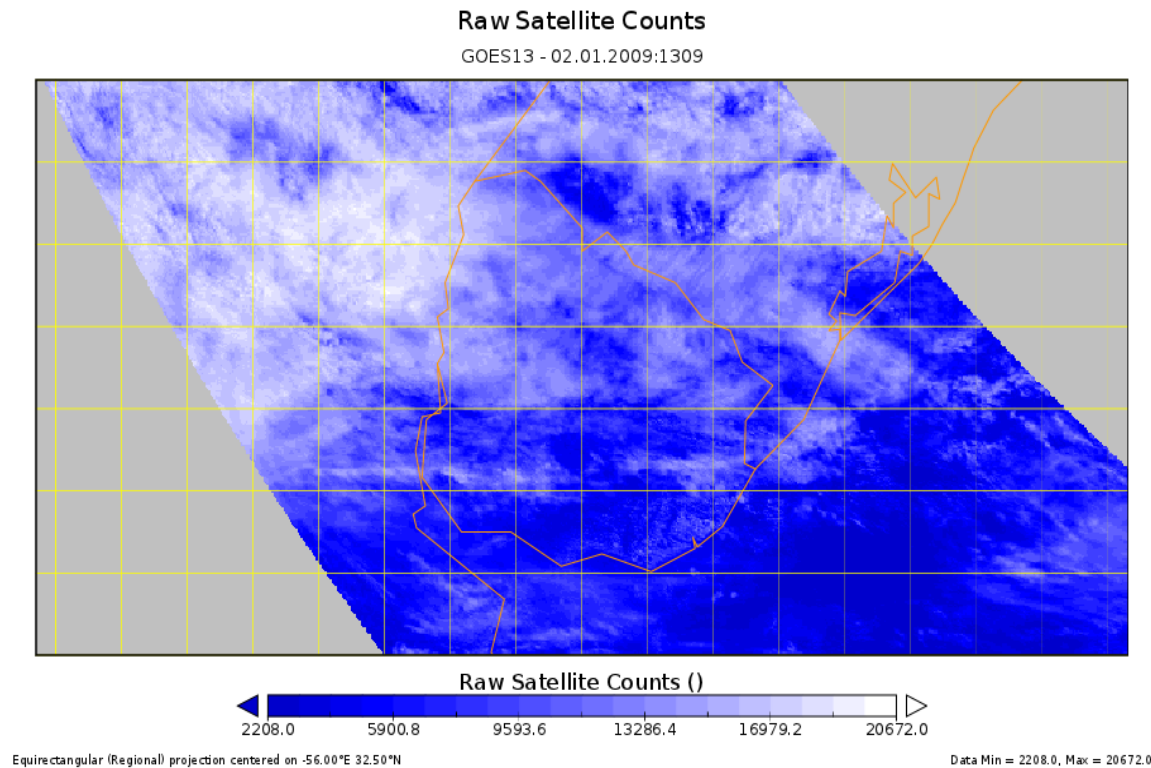
clear day part

Coefficients a , b , c , d are derived (by linear regression) from local ground data (statistical model)

GOES Satellite images

- VIS channel provides cloud cover information
- we use 9586 GOES 13 Images (april 2010 – june 2011)
- reduced images: cells of 10 x 10 min (19 x 16 km)

average
brightness
 B_m is computed
for each cell
and each hour



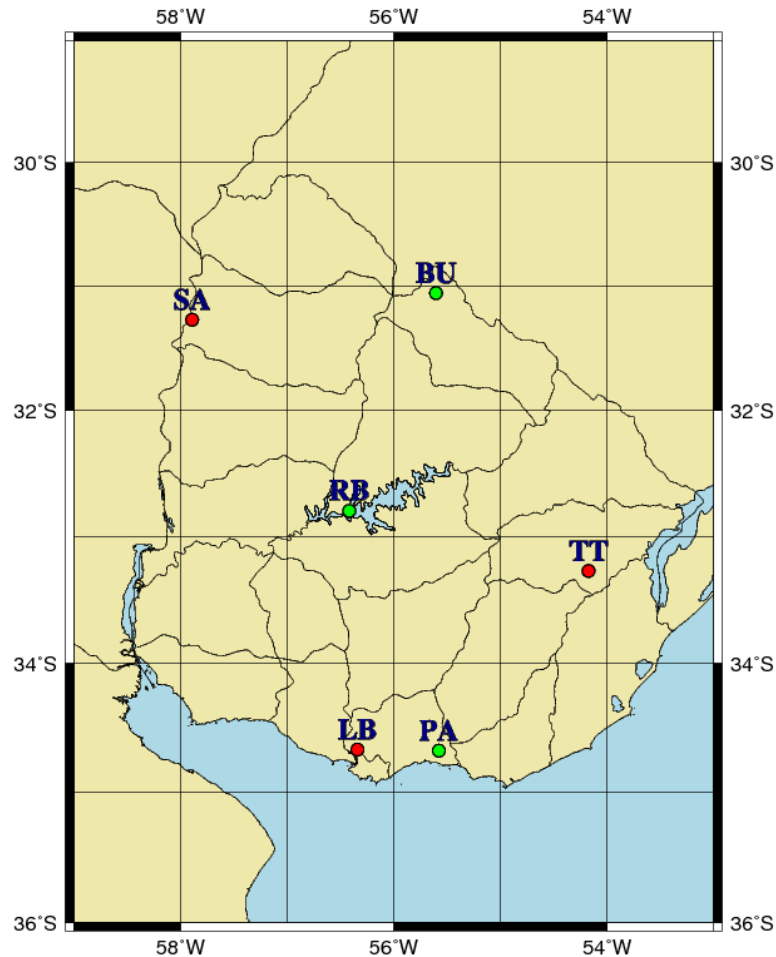
[past performance]

Most comparisons with ground data were done using Tarpley's original coefficients derived for the Great Plains, U.S.: ($a=0.4147$, $b=0.7165$, $c=-0.3909$, $d=-1.630 \text{ kJ/m}^2$)

days	time period	observed mean (MJ/m ²)	rms deviation (MJ/m ²)	relative rms (% mean)	sites	reference	location
282	1982	15.1	1.9	12.6	1	Justus, Paris, Tarpley, 1986	Georgia, U.S.
765	1982	15.7	2.1	13.6	5	Espoz & Brizuela, 1983	Argentina
5322	1982-1983	16.3	3.2	19.6	13	Frulla et al. 1988	Argentina
4404	1982-1983	15.8	3.2	20.3	9	Frulla et al. 1990	Southern part of Brazil
715	2000-2002			17.3	5	Righini and Barrera, 2008 (*)	Argentina

(*) a local implementation, compared against the training data set

Ground measurements



Training set:

- new Kipp & Zonen CMP6 pyranometers
- 3 sites, 9931 valid hours
- used to determine B0, a, b, c, d

training site	code	latitude	longitude	alt. (m)	time period
Las Brujas	LB	-34.672	-56.340	32	02/2010 :: 05/2011
Treinta y Tres	TT	-33.275	-54.172	100	05/2010 :: 05/2011
Salto	SA	-31.273	-57.891	50	06/2010 :: 05/2011

Testing set:

- 3 sites, 11317 valid hours
- new Li-Cor PV sensors
- used to evaluate the model

test site	code	latitude	longitude	time period
Rincón del Bonete	RB	-32.800	-56.416	04/2010 :: 04/2011
Buena Unión	BU	-31.058	-55.602	04/2010 :: 04/2011
Piedras de Afilas	PA	-34.682	-55.575	01/2010 :: 04/2011

[our implementation]

the clear day brightness field, B_0 depends on location, Julian day and hour angle.

- B_0 parametrization: [Tarpley, 1979]

$$B_0 = A + B \cos \theta_z + C \sin \theta_z \cos \gamma + D \sin \theta_z \cos^2 \gamma$$

- γ is the angle between satellite and Sun directions
- Initial seed and a suitable cloudiness filtering procedure yield A, B, C, D for each cell (location) and each day

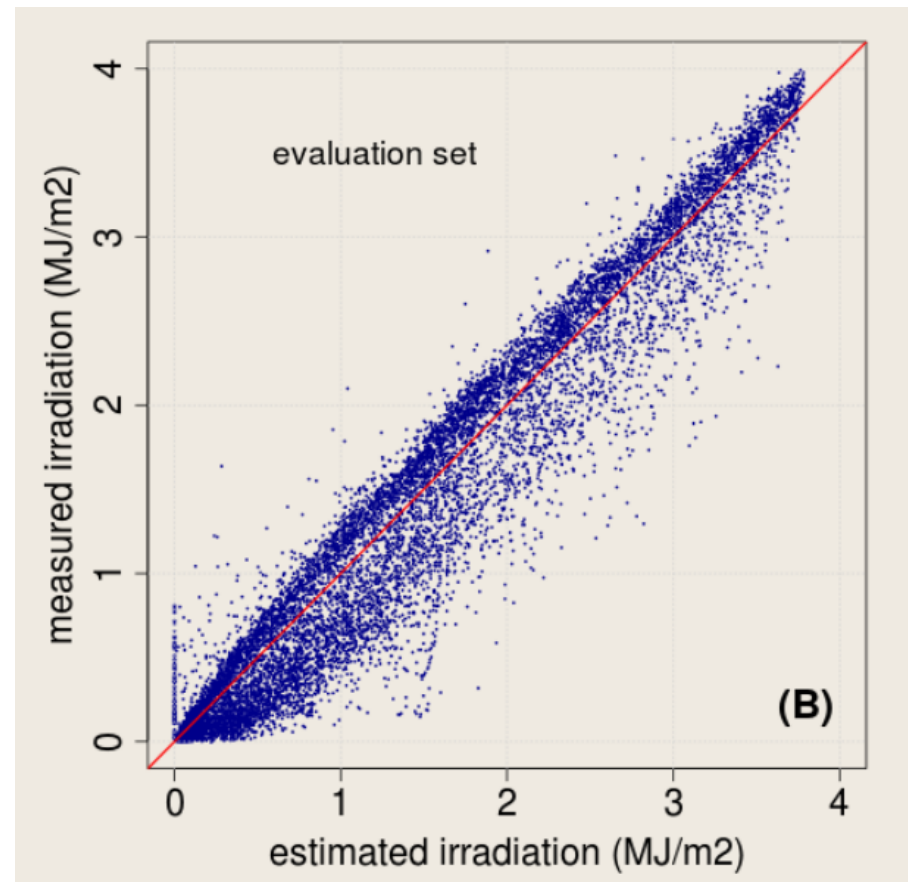
Our coefficients, obtained from linear regression, are

$a = 0.3016$, $b = 0.8628$, $c = -4101$, $d = -0.760 \text{ kJm}^{-2}$

Results

for hourly irradiation

- 11317 valid hours
- observed mean: 1.45 MJm^{-2}
- **rms deviation:** 0.29 MJm^{-2}
- relative rms deviation: 19.8%
- linear correlation: $\rho=0.968$



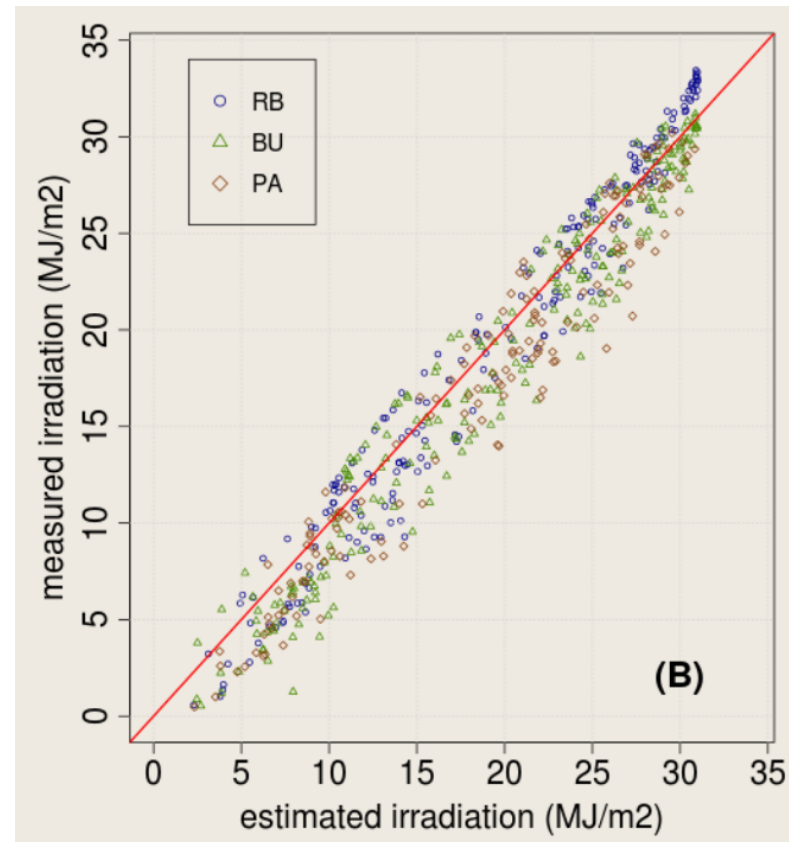
Results

for daily totals

- 578 site-days
- observed mean: 18.4 MJm^{-2}
- **rms deviation: 2.2 MJm^{-2}**
- rms: 11.8 % of the mean
- linear correlation: $\rho=0.975$

tendency:

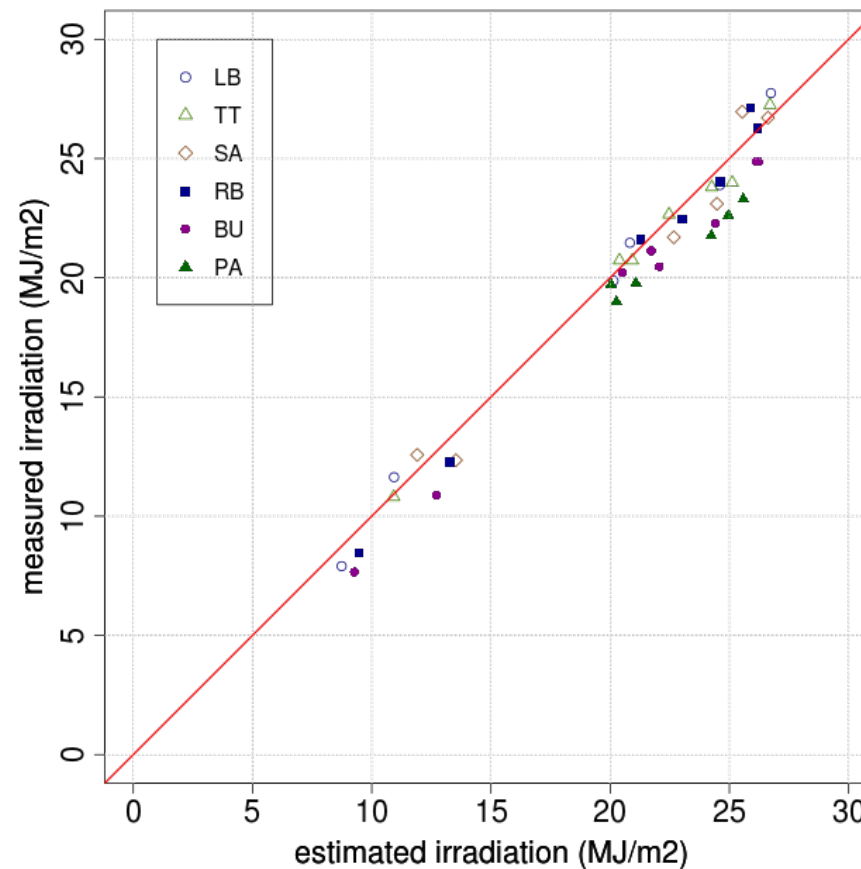
- overestimation in cloudy days.
- underestimation in clear days.



Results

for monthly averages,
of daily irradiation

- 21 site-months
 - observed mean: 20.0 MJm^{-2}
 - rms deviation: 1.4 MJm^{-2}
 - rms: 5.7 % of the mean
 - linear correlation: $\rho=0.985$
- for all six sites combined**



[Conclusions]

- good balance between simplicity and accuracy.
- daily rms deviates of $\sim 12\%$ against the testing set are encouraging (among the best, afwk).
- improve procedure for determining the ground albedo (B_0 field)
- long-term estimates for the 2000-2010 decade can be obtained after calibration of the images.
- Near future: use a physical radiation transfer model to estimate solar irradiation.

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Danke!

Thank you!

Gracias!

