Surface based cloud radiative forcing assessment at Dome-C Antarctic station (75°S) using BSRN data

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Introduction

Cloud Radiative Forcing: defined as the effect of cloudiness on the surface radiative budget *NetR*

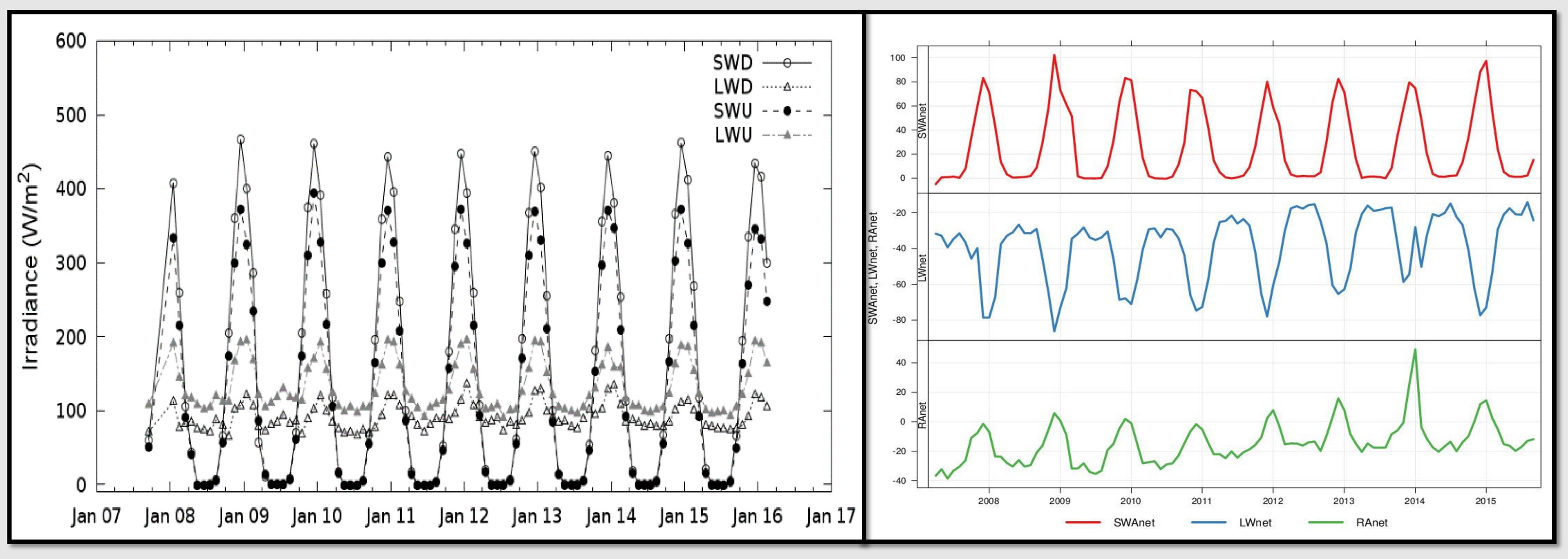
NetR = SWD – SWU + LWD – LWU

Cloud Radiative Forcing (CRF) = NetR-NetR$_{clr}$

where

NetR$_{clr}$ = SWD$_{clr}$ – SWU$_{clr}$ + LWD$_{clr}$ – LWU$_{clr}$

Data-set used: all the collected data (not only the BSRN quality checked)



We need models to represent the four clear sky fluxes. A methodology was applied, based on data acquired from radiometers, relying on accurate cloud screening to determine clear sky condition and subsequently to define semi-empirical clear fluxes.

Methodology

SW **CRF=(SWD–SWD$_{clr}$)–(SWU–SWU$_{clr}$)+(LWD–LWD$_{clr}$)-(LWU–LWU$_{clr}$)** **LW**

SWD$_{clr}$

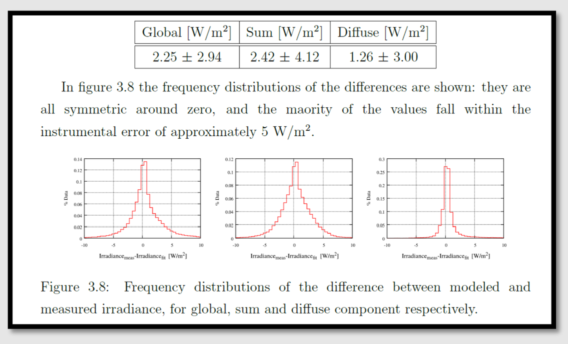
we used the well known Long & Ackerman (2000) method:

SWD$_{clr}$= a cos(SZA)^b

Here the average results for the SWD pyranometers ***g2*** (a,b), and for the method applied to [Dir+Dif] ***g1*** (a+,b+)

	a	a_+	b	b_+	N_{tot}
Summer	1400 ± 67	1394 ± 208	1.13 ± 0.04	1.13 ± 0.05	502
Autumn	1427 ± 93	1403 ± 87	1.14 ± 0.04	1.15 ± 0.04	331
Spring	1390 ± 116	1382 ± 115	1.12 ± 0.07	1.14 ± 0.04	215

Performances of fitting results

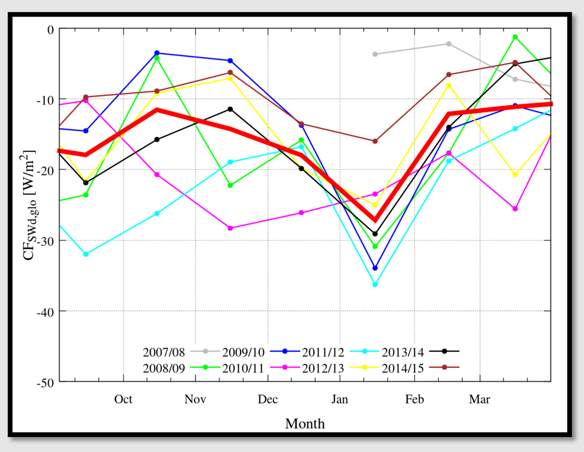


Global [W/m²]	Sum [W/m²]	Diffuse [W/m²]
2.25 ± 2.94	2.42 ± 4.12	1.26 ± 3.00

In figure 3.8 the frequency distributions of the differences are shown: they are all symmetric around zero, and the maority of the values fall within the instrumental error of approximately 5 W/m².

Figure 3.8: Frequency distributions of the difference between modeled and measured irradiance, for global, sum and diffuse component respectively.

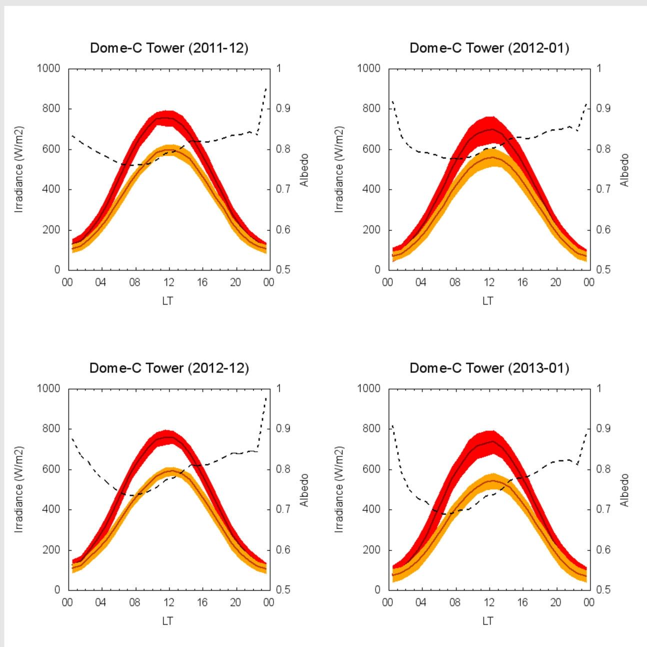
SWD cloud effect monthly averages



Cloudiness produces a negative effect ranging between -5 and -30 Wm^{-2}

SWU$_{clr}$

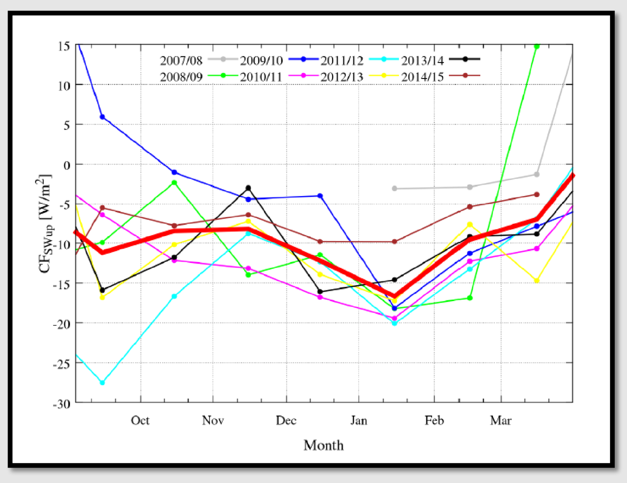
An anisotropy is present during the day



An empirical model was developed, depending on both SZA and azimuthal angle

$$F^{clear,A}_{\uparrow,SW} = \frac{A + B\cos(\phi-\phi_0) + C\cos(2(\phi-\phi_0))}{A+B+C}(D + E\cos(\theta) + F\cos^2(\theta))(a\mu^b) \quad (4.10)$$

SWU cloud effect monthly averages



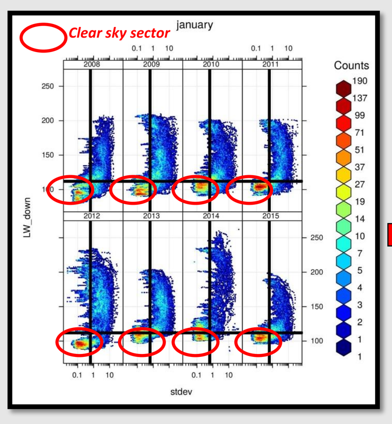
Cloudiness produces a negative effect ranging between -5 and -15 Wm^{-2}

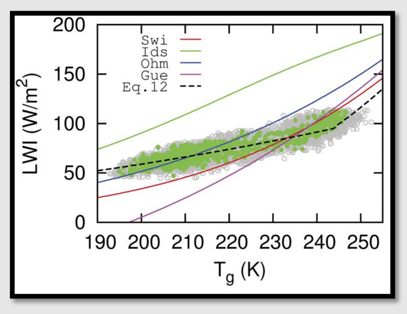
LWD$_{clr}$

A semi-empirical model based on the temperature of the top of inversion was adopted, Busetto et al. (2013)

$$LWD_{clr} = \varepsilon\sigma T_{400}^4$$

T_{400}(~constant with time *t*) is derived from $T_g(t)$, after a LWD cloud screening (Town et al., 2007)



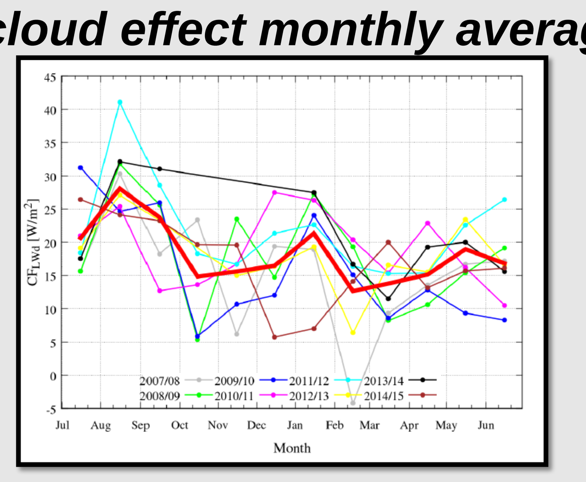


$T_g(t)$ has been used to simulate the temperature of the inversion layer removing daily and annual behavior. Main advantage: **wv** not required

$$LWD_{clr} = \varepsilon\,(T_{400}/T_g)^4\,\sigma\,T_g^4$$

$$\epsilon = -1.41 + 0.0077T_{400} - A_y\cos(\omega_y\,d + \phi_y)$$

LWD cloud effect monthly averages



The cloud effect appears on average ranging between +10 and +30 Wm^{-2}

LWU$_{clr}$

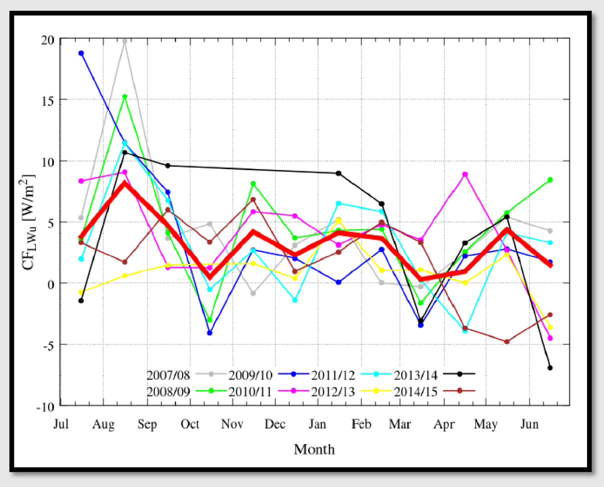
$$F^{clear}_{\uparrow,LW} = \epsilon_{snow}\sigma T^4_{skin} + (1-\epsilon_{snow})F^{clear}_{\downarrow,LW}$$

Comparing T_{skin} and T_g during clear sky condition, a linear relationship was found:

***T_{skin} = 0.01+1.04T_g** (r^2=0.97)*

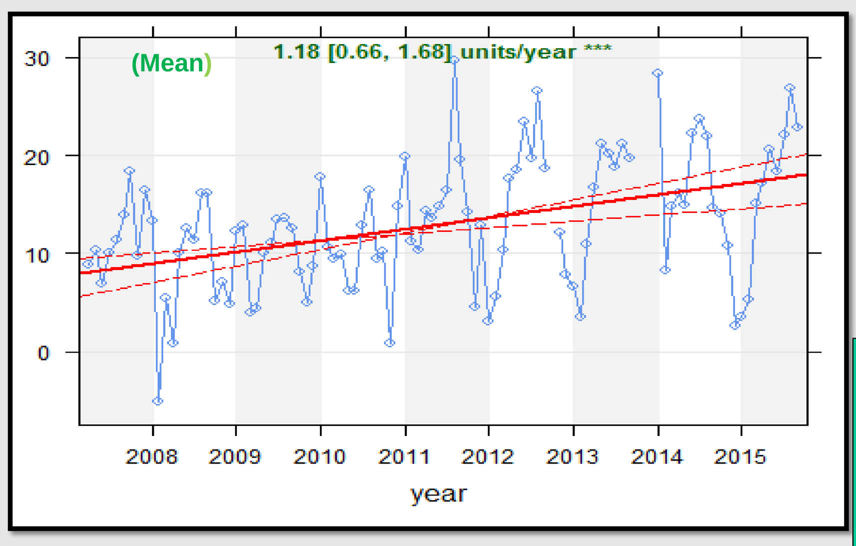
and assuming ε_{snow}=0.97, we defined the LWU$_{clr}$ time series: uncertainties were evaluated ranging within ±5Wm^{-2}, considering the error propagation in the formula above

LWU cloud effect monthly averages



The cloud effect appears on average ranging between 0 and +7 Wm^{-2}

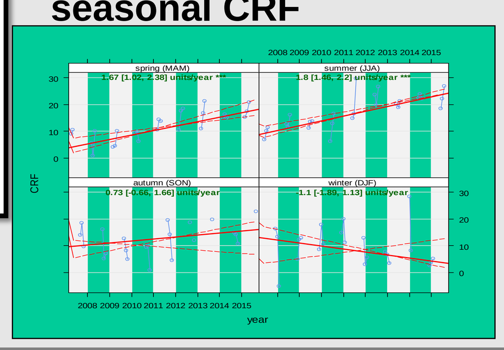
(Theil –Sen approach: median of all slopes [* => p<0.001])**



yearly CRF

	Mean ± Std [W/m²]
2007	11.87 ± 3.57
2008	10.21 ± 5.14
2009	10.74 ± 3.29
2010	10.47 ± 3.19
2011	13.87 ± 3.58
2012	16.48 ± 7.20
2013	16.87 ± 5.93
2014	15.45 ± 6.42
2015	17.23 ± 7.01

seasonal CRF



Conclusion:

1. **Positive CRF values ranging from 10-17 Wm^{-2} in the considered period with a significance trend that appears to be higher that expected if compared to global averaged brightening (+2Wm^{-2}, Wild et al., 2016)**
2. **The positive trend is similar to that observed for the LWD Cloud Effect, suggesting that this is the main component affecting our CRF result**
3. **This can likely to be an effect of the degradation of the calibration constant of LWD that affects clear measurements and not overcast measurements (when the signal is typically around 0).**
   *** $S_{CG4\#68}$ = µV/11.15 W/m² (2006-2011), $S_{CG4\#68}$ = 12.19 µV/W/m² since 2013.**
4. **Seasonal discrepancy: the austral summer behaves differently**
5. **The effect of blowing snow should be differentiated with respect to that of cloudiness.**
6. **The cloud screening based on LWD should be validate with respect to Long and Ackerman methodology**

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