



## Memòria justificativa de recerca de les convocatòries BCC, BE, BP, CTP-AIRE, INEFC i PIV

La memòria justificativa consta de les dues parts que venen a continuació:

- 1.- Dades bàsiques i resums
- 2.- Memòria del treball (informe científic)

Tots els camps són obligatoris

### 1.- Dades bàsiques i resums

Nom de la convocatòria

**Beatriu de Pinós (BP-DGR 2009), modalitat A**

Llegenda per a les convocatòries:

BCC	Convocatòria de beques per a joves membres de comunitats catalanes a l'exterior
BE	Beques per a estades per a la recerca fora de Catalunya
BP	Convocatòria d'ajuts postdoctorals dins del programa Beatriu de Pinós
CTP-AIRE	Ajuts per accions de cooperació en el marc de la comunitat de treball dels Pirineus. Ajuts de mobilitat de personal investigador.
INEFC	Beques predoctorals i de col·laboració, dins de l'àmbit de l'educació física i l'esport i les ciències aplicades a l'esport
PIV	Beques de recerca per a professors i investigadors visitants a Catalunya

**Títol del projecte:** ha de sintetitzar la temàtica científica del vostre document.

Temporal variability and trends of the downward solar radiation over Europe during the 20th century, with regional focus in the dimming/brightening phenomena on the Iberian Peninsula

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**Paraules clau:** cal que esmenteu cinc conceptes que defineixin el contingut de la vostra memòria.

Dimming/brightening, Europe, surface solar radiation, sunshine duration, trends

### Data de presentació de la justificació

24 Setembre 2012

Arturo Sánchez Lorenzo

Martín Wild



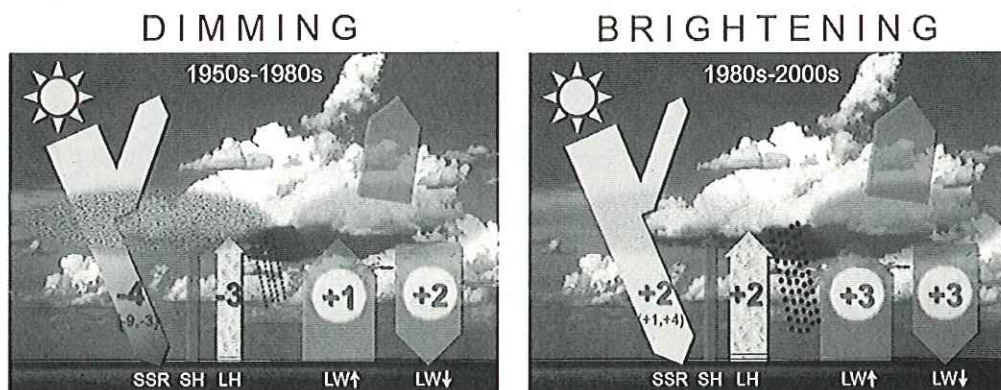


**Resum en anglès (màxim 300 paraules)**

La radiación solar que alcanza la superficie terrestre es un factor clave entre los procesos que controlan el clima de la Tierra, dado el papel que desempeñan en el balance energético y el ciclo hidrológico. Establecer su contribución al cambio climático reciente supone una gran dificultad debido a la complejidad de los procesos implicados, la gran cantidad de información requerida, y la incertidumbre de las bases de datos disponibles en la actualidad. Así, el objetivo principal del proyecto ha consistido en generar una base de datos de insolación incluyendo las series más largas (desde finales del siglo XIX) disponibles en toda Europa. Esta base de datos complementa para nuestro continente el Global Energy Balance Archive (GEBa) que mantiene y gestiona el grupo que ha acogido al receptor de la ayuda postdoctoral, y permite extender espacial (especialmente en países del sur de Europa) y temporalmente las series climáticas disponibles de mediciones de irradiancia solar. Como la insolación es un proxy de la irradiancia solar, el proyecto actual también ha tratado de calibrar de forma exhaustiva ambas variables, a fin de generar una nueva base de datos reconstruida de esta segunda variable que esté disponible desde finales del siglo XIX en Europa. Un segundo objetivo del proyecto ha consistido en continuar trabajando a escala de mayor detalle sobre la Península Ibérica, con el fin de proporcionar una mejor comprensión del fenómeno del “global dimming/brightening” y su impacto en el ciclo hidrológico y balance energético. Finalmente, un tercer objetivo del presente proyecto postdoctoral ha consistido en continuar estudiando los posibles ciclos semanales a gran escala de diferentes variables climáticas, línea de investigación de interés para la detección de posibles efectos de los aerosoles antrópicos en el clima a escalas temporales breves, y consecuentemente estrechamente vinculado al fenómeno del “global dimming/brightening”.

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**Figure 1.** Schematic representation of dimming and brightening. During “dimming” (1950s-1980s, left panel) the decline in SSR may have outweighed increasing atmospheric downwelling thermal radiation (LW from greenhouse gases, and counteracted global warming, causing only little increase in surface thermal emission (LW). The resulting reduction in radiative energy may have attenuated the latent heat flux (LH), leading to a slowdown of the water cycle. During “brightening” (1980s-2000s, right panel), the enhanced greenhouse effect has no longer been masked, causing more rapid warming, stronger evaporation/LH and an intensification of the water cycle. Values denote estimates changes in surface energy fluxes in  $\text{Wm}^{-2}$ . From Wild (2011).

However, both global dimming and brightening still have major uncertainties in their explanation and quantification, as was stated in the last IPCC Fourth Assessment Report (Trenberth et al., 2007, p. 279), or recently pointed out by Wild (2011):

1) There is a lack of reliable and long-term series of SSR, which are located mainly in or near cities. Consequently, some studies found that the dimming period is more evident in large urban areas as a consequence of local pollution, also called “urbanisation effect”, and might therefore not constitute a widespread phenomenon (e.g. Alpert et al., 2005).

2) Since widespread measurements of SSR were only initiated in 1957/58 within the framework of the International Geophysical Year, there is a lack of information on SSR variations before the 1950s. Moreover, an early brightening (Ohmura, 2009) during the first half of the 20th century has been identified over Europe at a few sites with SSR records before the 1950s (e.g. Stockholm, the longest SSR series, going back to 1923). However, its reliability is particularly uncertain due to scarce data availability.

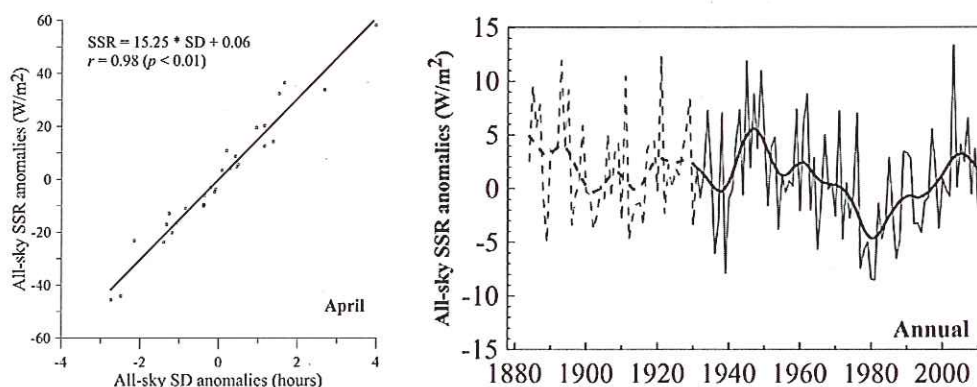
3) There is a lack of studies analysing SSR under clear sky (cloud free) conditions, as this requires a high temporal resolution of the SSR data together with collocated cloud cover information.

Summarizing, the main problem encountered in establishing the causes of global dimming and brightening is the limited number of SSR records with accurate and calibrated long-term measurements. To overcome this shortage, the analysis should be supported and extended with the help of other related climate variables, or proxy data, such as sunshine duration, which are much more widely available (Sanchez-Lorenzo et al., 2007; Wild, 2009, 2012).

Specifically, sunshine duration is defined as the time span, usually expressed in number of hours, that direct solar radiation exceeds a certain threshold (usually taken at  $120 \text{ Wm}^{-2}$ ). The measurements of this element were initiated as early as in the late 19th century. This variable is considered an excellent proxy measure of SSR at interannual and decadal scales (e.g. Stanhill, 2003; Wild, 2009), and plays an important role in the description of the dimming and brightening and their uncertainties (Stanhill and Cohen, 2001; Sanchez-Lorenzo et al., 2007, 2008, 2009; Wild, 2009, 2012). However, no attempt has been made so far to compile the many European distributed sunshine duration measurements in a single centralized dataset. A major aim of the proposed project was therefore the establishment of such a compilation, which was lacking in the scientific community.

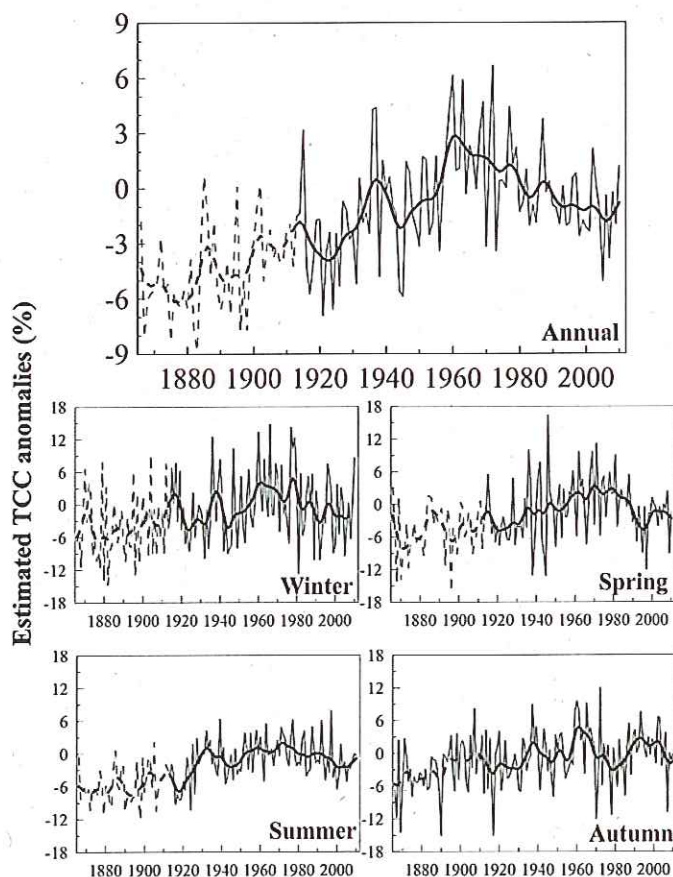
- The first study using the compiled dataset was focused on Switzerland. Specifically, the trends of all-sky SSR from 1885 to 2010 in Switzerland have been studied, which have been estimated using a homogenous dataset of 17 sunshine duration series. The sunshine duration records are shown to be a useful proxy measure of SSR at interannual and decadal scales in Switzerland (e.g. see Fig. 2). The results show that all-sky SSR has been fairly stable with little variations in the first half of the 20th century, unlike the second half of the 20<sup>th</sup> century that is characterized also in Switzerland by a dimming from the 1950s to the 1980s and a subsequent brightening. Cloud cover changes seem to explain the major part of the decadal variability observed in all-sky SSR, at least from 1885 to the 1970s; at this point, a discrepancy in the sign of the trend is visible in the all-sky SSR and cloud cover series from the 1970s to the present. Finally, in order to study the direct effect of the aerosols, it were also estimated clear-sky SSR series since the 1930s for a subset of the sites with collocated cloud cover observations. The mean clear-sky SSR series shows no relevant changes between the 1930s to the 1950s, then a decrease from the 1960s to 1970s, and ends with a strong increase from the 1980s up to the present. During the last three decades the estimated clear-sky SSR trends are in line with previous findings over Switzerland based on direct radiative flux measurements. Moreover, the signal of the El Chichón and Pinatubo volcanic eruption visible in the estimated clear-sky SSR records further demonstrates the potential to infer aerosol-induced radiation changes from sunshine duration observations.

- More recently, a subset of the dataset has been used for a reconstruction of the all-sky SSR variations since late 19th century in the whole Europe. The subset contains sunshine duration series over Europe with more than 70 years of data, some of them starting in late 19th century. The reconstructed SSR variations have been estimated by using the relationship found between the sunshine duration series and a satellite-derived SSR dataset (0.03 x 0.03 of spatial resolution), provided by the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) (Posselt et al., 2011), during the common 1983-2005 subperiod. The temporal evolution of the mean all-sky SSR annual series is characterized by a general decrease from the 1950s to the early 1980s, in agreement with the well-known global dimming phenomena. This is followed by a positive trend up to the present, which also matches with the brightening worldwide observed. Moreover, an “early brightening” has been detected during the first half of the 20th century, although regional differences are observed with areas over Europe where the all-sky SSR show no increase in this subperiod.



**Figure 2.** (Left) Example of the relationship between SSR (Y axis) and sunshine duration (X axis) mean monthly series representative of the whole Switzerland using data for the period 1981-2010. (Right) Estimated mean annual SSR series (thin series) from 1885 to 2010 for the whole Switzerland, plotted together with a low-pass filter (thick line). Previous to calculate the annual mean, the SSR monthly series has been estimated using the monthly fits between the sunshine duration and SSR series. Dashed lines are used before 1931 due to the lower number of stations with records before this period. The series are expressed as anomalies from the 1981–2010 mean. From Sanchez-Lorenzo and Wild (2012).

studies have documented the trends of the total cloud cover (TCC) and cloudy types; most of these studies focus on the trends since the second half of the 20th century. Due to the lower reliability of former observations, and the fact that most of this data is not accessible in digital format, there is a lack of studies focusing on the trends of cloudiness since the mid-19th century. In a first task, the applicant reviewed previous studies analyzing TCC changes with information covering at least the first half of the 20th century. Then, a specific work analyzing a database of cloudiness observations in Spain since the second half of the 19th century has been done. Specifically, monthly TCC series were reconstructed since 1866 by means of a so-called parameter of cloudiness, calculated from the number of cloudless and overcast days. These estimated TCC series show a high interannual and decadal correlation with the observed TCC series originally measured in oktas. After assessing the temporal homogeneity of the estimated TCC series, the mean annual and seasonal series for the whole of Spain (Fig. 3) and several subregions were calculated. The mean annual TCC shows a general tendency to increase from the beginning of the series until the 1960s; at this point, the trend becomes negative. The linear trend for the annual mean series, estimated over the 1866–2010 period, is a highly remarkable (and statistically significant) increase of +0.44 % per decade, which implies an overall increase of more than +6 % during the analyzed period. These results are in line with the majority of the trends observed in many areas of the world in previous studies, especially for the records before the 1950s when a widespread increase of TCC can be considered as a common feature.



**Figure 3.** Mean annual and seasonal estimated TCC (%) series (thin lines) from 1866 to 2010 in Spain, plotted together with a 13-year Gaussian low-pass filter (thick line). The series are expressed as anomalies from the 1971–2000 mean. Dashed lines are used before 1913 to indicate the lower number of series available before this year. From Sanchez-Lorenzo et al. (2012).

## 2.5. Conclusions

The main conclusions reached in the project can be summarized as:

- Sunshine duration records can be considered as an excellent proxy to estimate quantitatively all-sky and clear-sky SSR trends from the late 19th century up to the present over Europe. A dimming (brightening) is clearly visible in all-sky SSR during the 1950s–1970s (1980s–2000s) subperiod over Europe, in line with previous studies that used a lower density of stations. Equally, there is an early brightening period in some regions of Central and North Europe or a brief increase restricted to the 1940s (e.g. Switzerland).
- For Switzerland, the estimated all-sky SSR trends show a general agreement with cloud cover variability before the 1980s; at this point, a discrepancy in the sign of the trend is visible in the series. Equally, estimated clear-sky SSR provides evidence for the existence of periods where SSR over Switzerland is unrelated to TCC variations, particularly in the most recent parts of the records, which are possibly linked to changes in aerosol concentrations in the atmosphere.
- There is a strong relationship between the sunshine duration and temperatures over Europe. Interestingly, the series show a tendency towards higher correlations in the decadal series, both for different regions and temperature variables. These results confirm the relationship between temperature and sunshine duration over Europe since the second half of the 20th century, which has been speculated to partially decrease (increase) temperatures during the dimming (brightening) period.
- A new dataset of homogenous global (SSR) and diffuse (D) solar radiation series in Spain since the 1980s has been developed. SSR showed a significant positive trend of  $+3.93 \text{ Wm}^{-2}$  per decade during the 1985–2010 period. The seasonal mean series also showed significant increases, with the strongest rate in summer. Regarding the D series, the most interesting feature is the overall decrease observed in the annual mean series from 1985 to 2010 ( $-2.09 \text{ Wm}^{-2}$  per decade), which is mainly dominated by the trends of the summer and spring seasons. A clear increase in the D records is observed in 1992, probably as a result of enhanced scattering produced by aerosols emitted by the Pinatubo volcanic eruption.
- A widespread increase of total cloud cover (TCC) is observed during the 20th century over most of the reviewed studies. Equally, an increase of the TCC is confirmed in Spain since the second half of the 19th century, especially from the early 20th century to the 1960s/70s during the summertime, followed by a decrease up to the present.
- A decrease in pan evaporation (1981–2010 period) is observed in Spain, which cannot be explained by the observed increase in solar radiation. On the other hand, evaporation trends estimated by the Piche evaporimeter provide a better agreement with solar radiation and sunshine trends.
- Regarding the reported significant large-scale weekly cycles (WCs), there is not a consistent spatial pattern in the results. In fact, the different methodologies, meteorological variables, and data periods used for the analyses make it difficult to conclude that the large-scale WCs are real, or at least easily detectable in climate series. Nevertheless, an existence of significant WCs over North America seems plausible, especially in the south-eastern of the US.
- Higher values of cloud cover and aerosol optical depth are observed during midweek in the summer over Central Europe, while an opposite cycle appears over the Iberian Peninsula and Northeastern Europe.

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- You, Q., Sanchez-Lorenzo, A., Wild, M., Folini, D., Fraedrich, K., Ren, G., and Kang, S. (2012): Decadal variation of surface solar radiation in the Tibetan Plateau from observations, reanalysis and model simulations, *Clim. Dynam.*, in press, doi: 10.1007/s00382-012-1383-3.

## 2.7. Main publications and meeting presentations developed during this project

### 2.7.1. Publications

- Sanchez-Lorenzo, A.**; Calbó, J. and Wild, M. (2012): Global and diffuse solar radiation in Spain: building a homogeneous dataset and assessing their trends, *Global and Planetary Change*, under review.
- van den Besselaar, E.J.M.; **Sanchez-Lorenzo, A.**; Wild, M. and Klein Tank, A.M.G.: Relationship between the dimming/brightening and temperatures across Europe since the second half of the 20th century, *Journal of Geophysical Research*, under review.
- Sanchez-Lorenzo, A.**; Wild, M. and Trentmann, J. (2012) (2012): Suitability of a high-resolution satellite-derived product for an assessment of the mean and trends in surface solar radiation over Europe, *Journal of Geophysical Research*, under review.
- Sanchez-Lorenzo, A.**; Trentmann, J. and Wild, M. (2012): Validation of the Monthly Surface Solar Radiation over Europe Derived From the CM SAF Dataset against Homogenized GEBA Series (1983-2005), *Proceedings of the International Radiation Symposium 2012*, in press.
- Hakuba, A.; **Sanchez-Lorenzo, A.**; Folini, D. and Wild, M. (2012): Testing the Homogeneity of Short-Term Surface Solar Radiation Series in Europe, *Proceedings of the International Radiation Symposium 2012*, in press.

- Sanchez-Lorenzo, A., Wild, M., van den Besselaar, E.J.M., Stanhill, G., Butler, C.J., Klein Tank, A.M.G., Pallé (2012):** Trends of reconstructed surface radiation in Europe since late 19th century. International Radiation Symposium 2012, 06 – 10 August 2012, Dahlem Cube, Berlin, Germany. Oral communication.
- Sanchez-Lorenzo, A., Azorin-Molina, C., Wild, M., Vicente-Serrano, S.M., López-Moreno, J.I. (2012):** Feasibility of sunshine duration records to detect changes in atmospheric aerosols: review and new evidences. International Radiation Symposium 2012, 06 – 10 August 2012, Dahlem Cube, Berlin, Germany. Poster.
- Hakuba, M. Z., Wild, M., Folini, D., Sanchez-Lorenzo, A., Schaepman-Strub, G. (2012):** Solar absorption in the climate system estimated from surface radiation measurements and collocated satellite products. International Radiation Symposium 2012, 06 – 10 August 2012, Dahlem Cube, Berlin, Germany. Poster.
- Sanchez-Lorenzo A. (2012):** Decadal variations of estimated surface solar radiation in Europe since the beginning of the 20th century. DWD Seminar, Deutscher Wetterdienst, 6th June, Offenbach. Invited seminar.
- Sanchez-Lorenzo A., Laux P., Hendricks-Franssen H.J., Georgoulias A.K., Calbó J., Vogl S., Quaas J. (2012):** Weekly cycles in meteorological variables over large-scales: fact or myth?. 11th International Conference on Meteorology, Climatology and Atmospheric Physics, Athens, Greece, 29 May-1 June, 2012. Oral communication.
- Georgoulias A.K., Kourtidis K.A., Alexandri G., Sanchez-Lorenzo A. (2012):** Summer total cloud cover weekly variability over Europe: sign of aerosols' indirect effect?. 11th International Conference on Meteorology, Climatology and Atmospheric Physics, Athens, Greece, 29 May-1 June, 2012. Oral communication.
- Sanchez-Lorenzo, A. and Wild, M. (2012):** Variability and trends of reconstructed surface radiation in Switzerland since late 19th century. EGU General Assembly 2012, 22-27 April, Vienna.
- Sanchez-Lorenzo, A.; Calbó, J. and Wild, M. (2012):** New surface solar radiation and evaporation datasets in Spain: in search of a better understanding of the dimming/brightening. EGU General Assembly 2012, 22-27 April, Vienna.
- van den Besselaar, E.J.M.; Sanchez-Lorenzo, A.; Wild, M. and Klein Tank, A.M.G. (2012):** Possible role of the dimming/brightening in observed temperatures across Europe since the second half of the 20th century. EGU General Assembly 2012, 22-27 April, Vienna.
- Hakuba, M. Z.; Wild, M.; Folini, D.; Sanchez-Lorenzo, A. and Schaepman-Strub, G. (2012):** Solar absorption estimated from surface radiation measurements and collocated satellite products. EGU General Assembly 2012, 22-27 April, Vienna.
- You, Q.; Sanchez-Lorenzo, A.; Wild, M.; Folini, D. and Fraedrich, M. (2012):** Surface solar radiation in the Tibetan Plateau from observations, reanalysis and model simulations. EGU General Assembly 2012, 22-27 April, Vienna.
- Pereira, P.; Sanchez-Lorenzo, A.; Lopez-Bustins, J.-A. and Lolis, C.-J. (2012):** Trends in summer tropical nights on the Iberian Peninsula and their connection with large-scale atmospheric circulation patterns. EGU General Assembly 2012, 22-27 April, Vienna.
- Georgoulias A.K., Kourtidis K.A., Alexandri G., Sanchez-Lorenzo A. (2012),** Summer total cloud cover, aerosol and precipitation weekly variabilities over Europe: signs of the aerosol indirect effect?, International Conference on Air Quality - Science and Application (Air Quality 2012), Athens, Greece, 19-23 March, 2012. Oral communication.
- Sanchez-Lorenzo, A. and Wild, M. (2011):** Trends of surface solar radiation in a mountain region of Central Europe since the late 19th century, WCRP Open Science Conference, 24-28 October, Denver, USA.
- Wild, M.; Folini, D.; Sanchez-Lorenzo, A. and Dutton, E. (2011):** Decadal changes in surface radiative fluxes - overview and update. WCRP Open Science Conference, 24-28 October, Denver, USA.