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Solar Energy Resource Assessment in Chile: Satellite estimation and ground station measurement

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Abstract

The progress from the last four years in solar energy resource assessment for Chile is reported, including measurements from a ground station network spanning from two to three years of data, and satellite estimations from the recently developed Chile-SR model including two full years of data. The model introduces different treatments for the meteorological variables and the effective cloud cover computations which allow estimation of the global horizontal irradiation on an hourly basis. The BRL model of diffuse radiation is then applied in order to estimate the diffuse fraction and diffuse irradiation, from which the Direct horizontal irradiation is then computed. Direct normal irradiation is computed by applying proper solar geometry corrections to the direct horizontal irradiation. The satellite estimation model was developed as an adaptation from Brazil-SR model, with an improved formulation for altitude-corrected atmospheric parameters, and a novel formulation for calculating effective cloud covers while at the same time detecting and differentiating it from snow covers and salt lakes. The model is validated by comparison with ground station data. The results indicate that there are high radiation levels throughout the country. In particular, northern Chile is endowed with one of the highest solar resources in the world, although the resource variability is higher than previously thought.

Keywords: Solar resource assessment, Chile, ground measurements, satellite estimation, cloud cover estimation.

1. The Need for Solar Energy Data in Chile

Renewable Energy promotion in Chile has obtained institutional support by means of a law that mandates a renewable energy quota of up to 10% of the electrical energy generated, which must be met by

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2024, with public announcements already being made that would modify this goal in order to achieve 20% of power generation by 2020 from renewable energy [1]. This plan has sparked interest in introducing renewable energy systems to the country´s electricity system. Solar energy is currently at the initial stages of market penetration, with several projects being announced including PV, CSP, and industrial heat supply plants. However, strong barriers still exists due to the absence of a valid solar energy database, adequate for energy system simulation and planning activities. In fact, the current state of Solar Energy utilization in Chile is rather unsatisfactory. Even as the country is being endowed with an exceptional solar potential, the contribution of solar energy to the energy mix in Chile is negligible. Only 3.44 MW of PV have been deployed and are currently operating with 69 MW being built [2], and even when there have been several announcements for commercial and demonstration plants, no other projects are currently being executed -either PV or CSP- but for the process heat plant being built at Minera El Tesoro in northern Chile [3]. As of June 2013, the environmental impact assessment system listed a total of 4012 MW of solar plants already approved that have not yet initiated construction and 2201 MW entered for evaluation, of which 360 MW correspond to a single CSP project (4x90 MW) and the rest are PV plants. However, according to the Chilean Government Renewable Energy Center (CER) [4], none of the projects has already secured funding and are facing serious financial difficulties. Regarding solar heating and cooling systems, statistics from the "Solar Program" at the Energy Ministry indicate that as of 2011 there are 58,000 m^2 of installed solar thermal collectors for both the residential and commercial sectors, projected to reach 190,000 m^2 by 2015 [5]. There are currently no solar desalination projects in Chile. One of the several reasons that explain this difficulty in financing solar projects lies in the lack of adequate resource assessment activities that could allow reducing the risk associated to the real energy yield of the solar plants to be deployed in Chile. The efforts of our research team aim to produce and make available to the public and industry a proper set of solar radiation data able to allow project development with lower resource-related uncertainty.

Previous reports by the authors identified several databases of solar radiation which are available for Chile and discussed their merits and shortcomings. It has been found that significant deviation exists between sources, and that all ground station measurements display unknown uncertainty levels, thus highlighting the need for a proper, country-wide long-term resource assessment initiative. However, the solar energy levels throughout the country can be considered as high, and it is thought that they are adequate for energy planning activities –although not yet for proper power plant design and dimensioning. As a general conclusion, the previous work by the authors demonstrated that although for Chile there are several databases of ground measurements, a weather simulation model, and satellite-derived data, none of these data sources are completely valid and therefore a nationwide effort of resource assessment was needed [6-8].

As context, it is possible to mention that solar radiation data for large spatial regions can be obtained from ground station networks that provide discrete data points from which a continuous map can be obtained by means of a proper interpolation scheme. In addition, surface radiation can be estimated by satellite data processing. The latest Brazilian Solar Atlas [9], for example, combines both measurement techniques in order to obtain data with low uncertainty levels. Pyranometer-based measurements from ground stations typically have lower uncertainty levels that satellite-derived data obtained by radiative transfer models, although this cannot be guaranteed for locations in between stations for data that has been