Abstract

The balancing of the wind and solar energy resources in Andalusia (southern Iberian Peninsula) is analyzed using results from numerical weather prediction model (NWP) integration. Particularly results for one year (2007) integration, of 9 km of spatial resolution and 1 hour of time resolution, based on the WRF (Weather and Research Forecasting model). NWP were analyzed. A Canonical Correlation Analysis (CCA) was performed on the wind speed and global radiation fields obtained from this integration, allowing to obtain areas of high/low balancing for the wind and solar energy resources. The analysis was carried out separately for the different seasons of the year. In addition, different time filter (synoptic to seasonal) were applied to the data. The region of study is located in a transition zone from middle latitudes to subtropical climates, with the Atlantic Ocean and the Mediterranean region in the southern bound. In addition, it presents a very complex topography. This allows to properly evaluating the balancing effect of the two renewable energy resources along the region and provides the results with a greater representativeness than those derived from just a regional study. Results showed a considerable balance between the wind and solar resources mainly in the mountain areas of the interior of the region, along the coast in the southern part of the region and, specially, in the coastal area near the Strait of Gibraltar. The reasons behind these balancing effects are widely discussed.

Methods

Dynamic downscaling

The simulation was carried out with the Weather Research and Forecasting model (WRF). Skamarock et al. (2005).

Spatial configuration:
- 2 two-ways nested domains with 27 and 9 km of resolution.
- 27 vertical levels.

Physical configuration:
- Longwave radiation: RRTM scheme.
- Shortwave radiation: Dudhia scheme.
- Land-surface option: RUC scheme.
- Boundary-layer option: YSU scheme.
- Cumulus option: Kain-Fritsch scheme.
- Microphysics: Thompson

Global Forecast System (GFS) model output with spatial resolution 1º x 1º every 6 hours were used. The daily solar irradiance and daily wind energy were computed using the outputs.

Balance of resources

The balancing study was carried out from two points of view:

- Correlation cell to cell:
  The correlation between daily wind energy and daily solar irradiance was calculated for all cells for the nested domain.

- CCA Barnett-Preisendorfer method:
  Following Barnett and Preisendorfer, (1987) and Bretherton et al. (1992) this method can be separated into two steps:
  
  First step: Principal component analysis filtering. The aim is to select the number of patterns necessary to explain at least the 70 % of the total variance for each field. In the present work, the five first patterns were selected for each field.
  
  Second step: Canonical correlation analysis was carried out using the results of the first step. Finally the patterns from CCA was project over the patterns of PCA to get the final maps. Each study was carried out for seasonal and annual periods and for filtered and for raw data. The aim of the filtering stage is to get the synoptic effects (2 to 4 days). A non recursive filter of order 5 with a Hamming window, was selected. More details in Lynch et al (1995). In this work, the first 3 patterns was analyzed for each case.

Results

In this section the results for the raw data are presented.

Correlation cell to cell

The negative values of the correlation can provide useful information about the balancing of wind and solar energy. It means that the temporal series of the resources are in opposite phase. Negative correlation values have been obtained for spring (northern Africa), summer (east of Iberian Peninsula) and autumn (over Andalusia).

CCA Barnett-Preisendorfer method

Unlike the correlation cell to cell, the CCA Barnett-Preisendorfer method provides information about the regional balancing between resources. The maps below show the first patterns for autumn. Figures a) and b) show the loadings for solar energy and wind energy, respectively. The first pattern explains the 60.8% of the total variance for solar energy and the 25% for wind energy. Figure c) shows the temporal series associated with the first pattern for solar energy (red) and wind energy (blue). In order to understand the origins of the balancing, it is necessary an interpretation of the associated synoptic situation. Particularly, Figure d) shows the mean synoptic situation for the 5 maximum values of wind energy scores. In these maps the anomalies for solar radiation and wind are presented. Figure e) is similar to Figure d) but referred to the 5 minimum values of wind energy.

Conclusions

- The balancing has a strongly dependence on the studied period.
- Winter: With the CCA Barnett-Preisendorfer method a weak balancing was found for the second pattern (Strait of Gibraltar) and the third pattern (western of Andalusia). No balancing was obtained from the correlation cell to cell.
- Spring: With the CCA Barnett-Preisendorfer method, a balancing was found for the first patterns (Strait of Gibraltar area), for the second pattern (northern Africa) and for the third pattern (eastern coast of Andalusia). Analyzing the correlation cell to cell, balancing was found in northern Africa.
- Summer: With the CCA Barnett-Preisendorfer method, a balancing was found in the Strait of Gibraltar area (first and third pattern) and in center of the coast of Andalusia (second pattern). Analyzing the correlation cell to cell, the balancing was found in the eastern of the studied area.
- Autumn: With both methods, a balancing was found over the whole study region.

References