Availability of Solar, Wind and Hydropower Across Europe

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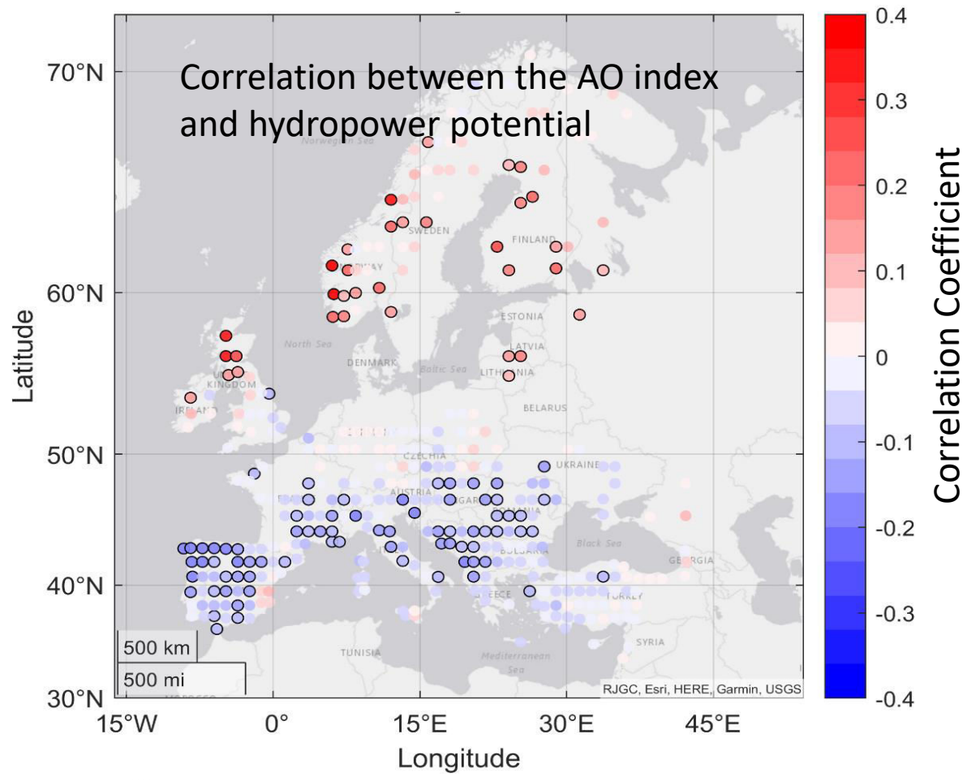
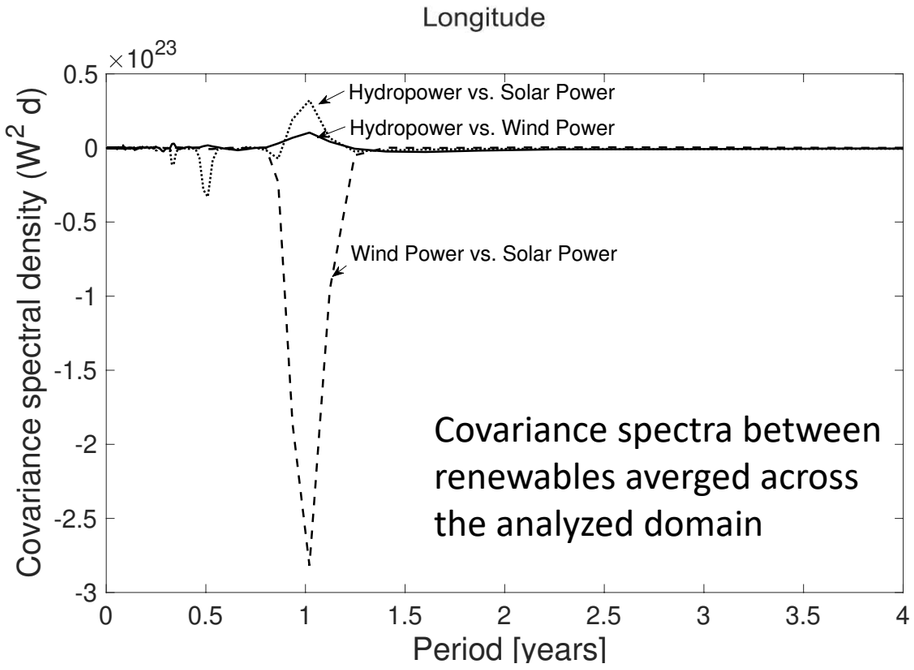
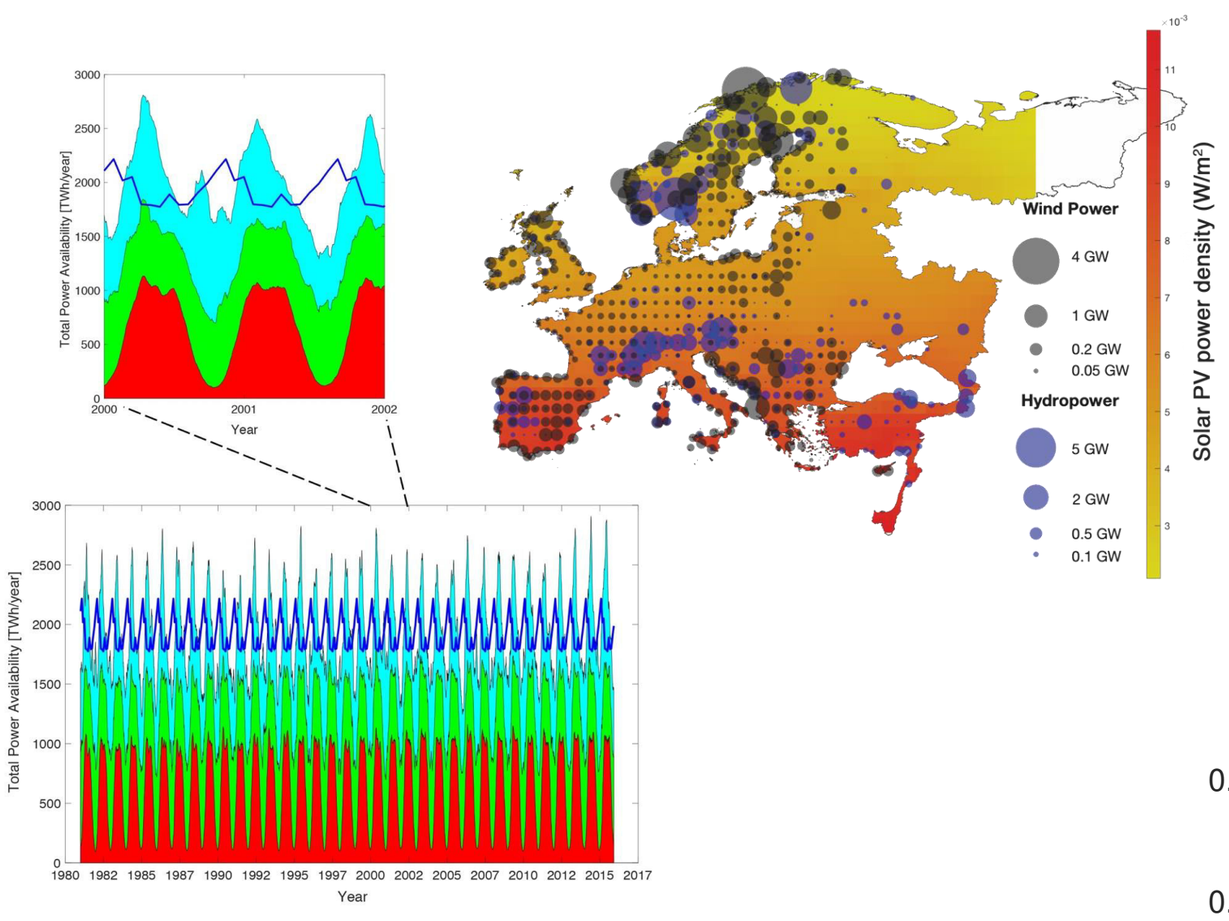
Abstract

Forecasts of the availability of renewable energies can be focused on the long-term statistically behaviour and occurrence of energy droughts that control the energy storage demand and security of renewable electricity production. In an ongoing research project funded by the Swedish Energy Agency, we have used a 35-year historical record of daily climatic data covering the European continent to reveal the spatio-temporal characteristics in renewable energies. By means of spectral decomposition of these time-series we find that spatial-temporal coordination of renewable electricity production from solar, wind and hydro can contribute to several times higher reduction of the energy storage demand – Virtual Energy Storage Gain (VESG) – than storage existing in the current European hydropower. Furthermore, we also find that solar, wind and hydropower production can meet the entire electricity consumption of Europe by using only existing energy storage available in hydropower in combination with spatio-temporal coordination and appropriate resource complementarity from wind and solar power.







Spatio-temporal pattern in renewable energies

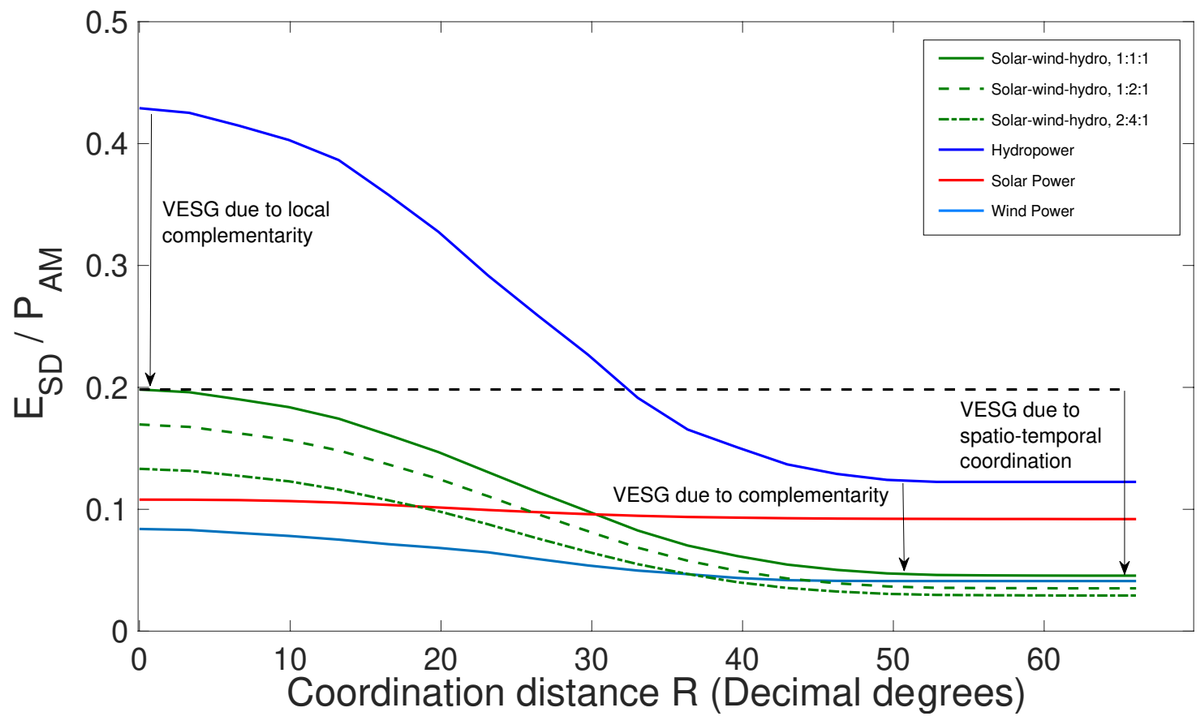
The uppermost graph illustrates that there is a complementing pattern in energy availability along the south-to-north direction in Europe. Similarly, there is a temporal covariation pattern between the renewable sources as stressed by the lower graph. A negative covariation on the annual period between solar and wind power indicates a beneficial complementary behaviour.

Renewable energy scenario and supporting methods

Scenarios
One standpoint for our technical scenario is that the current hydropower production capacity is conserved as is, i.e. with an annual production capacity of 642 TWh/y and a storage capacity of 183 TWh in the region shown in the above map. We have considered expansion of wind power at the current land-based locations of windfarms and solar power at a uniform spatial distribution.

Hydro-climatic and consumption data
Hydroclimatic data for the period is taken from Copernicus ECMWF database, hydropower data from the GranD data base and windfarm data from the World Windfarm database. Electricity consumption data was obtained from Eurostat.

Analytical approach
Spectral decomposition of the energy balancing problem facilitates separation of the climatic influence on relevant frequencies and to express the “Virtual Energy Storage Gain” on these frequencies.



Findings

The above graph illustrates how the energy storage demand (E_{SD}) decreases with coordination distance and various shares of solar, wind and hydropower across Europe (P_{AM} being the annual mean energy production). Solar, wind and hydropower production can meet the entire electricity consumption of Europe, 4,950 TWh/y over a regulatory horizon of 3 - 5 years, by using only existing energy storage available in hydropower in combination with spatio-temporal coordination and appropriate resource complementarity from wind and solar power.

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