A FIRST APPROACH TO CONSIDERING THE INFORMATION OF THE MADDEN-JULIAN OSCILLATION IN THE OPERATION OF THE ELECTRICAL SYSTEM OF URUGUAY

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Overview

The Madden-Julian Oscillation or MJO [1] is an intraseasonal (30-90 days) disturbance in the tropical atmosphere. It is the dominant component of the intraseasonal variability in the tropical atmosphere, favoring different climatic configurations in remote regions. It is an eastwards propagating cell characterized by an enhanced and suppressed convective region. The evolution of MJO is most typically represented by the RMM index [2], which, considering winds at different atmospheric levels, defines a phase (related to the location of the cell) and an intensity (related to the amplitude) of the oscillation.

The importance of the MJO lies in the fact that it can be predicted with a lead time of five weeks [3] and then predict worldwide consequences. In particular, the effects of MJO in Southeastern South America have been analyzed in many publications. For example, [4] find that during austral summer phases 3, 4, and 5 favor simultaneous weekly rainfall in the upper tercile in Uruguay and southern Brazil (a region that influences the flow in the most important Uruguayan hydroelectric power plant) while in austral autumn phases, 4, 5 and 6 (8) are associated to enhanced (reduced) precipitation, in spring phases 4 and 5 are associated with upper tercile and in winter the relationship is less important. Also, The work [5] conclude that the persistence of MJO for more than five days in phases 4 and 5 during austral spring is a precursor to extreme rainfall events in southern Uruguay.

In 2023 the uruguayan power system supplied a national demand of 11472 GWh plus an export of a 244 GWh. This energy was fullfiled 39% by wind, 3% by solar, 9% by biomass, 28% by hydro, 8% by fuel-fired units and 12% by imports.

The Uruguayan precipitation regime imposes great variability in the annual energy available from this source. The annual generation of the hydroelectric subsystem varies between 3300 and 9300 GWh with an almost uniform distribution. The largest lake, at the beginning of the Río Negro, has the capacity to store 136 days of total generation from the chain of three hydroelectric plants with an installed capacity of 596 MW downstream. Additionally, on the Uruguay River there is the bi-national Salto Grande hydroelectric plant with an installed capacity of 1800 MW and storage capacity of only 5 days. This plant is shared equally between Argentina and Uruguay.

National demand is about 1,300 MW (annual average) with peak values of about 2,200 MW and minimum values of around 700 MW. The sum of wind (1,550 MW) and solar (220 MW) installed capacity exceeds the daily peak demand on 70% of the days of the year.

For the optimal operation of the system, the main challenge is the valorization of the water from the three main lakes, which is carried out using the SimSEE platform. The Electricity Market Administration (ADME) carries out the programming of the operation of the National Interconnected System. (NIS). To do this, it uses two robots Vates_MP and Vates_CP [6] that are constantly assimilating information on the state of the NIS and the forecasts of the surface temperature anomaly of the Pacific Ocean, flow rates of contributions to the lakes, and wind speed. , solar radiation and temperature.

In 2010, the work [7] was carried out, which was the starting point for the incorporation of the ENSO phenomenon forecasts in the energy dispatch programming of Uruguay. In this work, a similar analysis is presented, as a first step in considering the MJO information in the country's energy programming.

Methods

The state of the MJO is determined by the RMM1 and RMM2 components. Based on these components, the phase and module of the vector (RMM1, RMM2) are established and based on said phase and module, dependencies of the precipitation distributions in different parts of the globe are presented. MJO influences climate conditions in many regions of the world. This influence depends on the state of the oscillation, which is indicated by the RMM index (computed from RMM1 and RMM2 components).

To incorporate this information into the energy dispatch models, it is necessary to translate these dependencies into the corresponding ones on the distributions of the water inflows to the dams. To represent these dependencies, the Correlations in Gaussian Spaces with Histograms CEGH [8] models were used. The system corresponding to the year 2023 were considered and said structure was maintained fixed for 8 years for the purposes of measuring changes in the optimal operation of the system by incorporating the information provided by the MJO. Two CEGH models were trained for the contributions of incoming water flows to the lakes associated with the hydroelectric plants. The first CEGH_LI (less informed) modeling the stochastic process of the variables iN34 (index that represents ENSO) and B, P and S50 that correspond to the hydraulic contributions to the lake of Rincón de Bonete, Palmar and Salto Grande (50% corresponding to Uruguay). The second CEGH_MI (more informed) adding to the previous variables the RMM1 and RMM2 components that determine the status of the MJO.

Using each of these models, two Operators were trained that we will respectively call Less Informed Operator (LIO) and More Informed Operator (MIO). In theory, each Operator is optimal to operate the system if reality behaves like the model with which it was trained. To calculate an estimate of the value of the information provided by knowledge of the state of the MJO, the expected value of the cost of the operation for the next 8 years was calculated, with the operation performed by LIO and MIO but in simulations with the CEGH_MI model.

Results

The Fig.1 shows the correlations of iN34 (ENSO index) and MJO with incoming hydropower for different days in advance. The first thing to observe is that the iN34 index presents correlations with the influent hydraulic energy of the order of 3 times higher than those observed with the components of the MJO and with permanence in the analyzed horizon. The first 10 days are generally informed by the assimilation of flow forecasts into the stochastic models used to schedule energy dispatch. The possible contribution of new information from the MJO is then in the time horizon after those first 10 days. As can be seen in the figure, the RMM2 component presents a relevant correlation with the influent hydraulic energy 15 days in advance.

The Fig.2 shows the future operation cost using LIO and MIO for 1000 the simulations based on the realizations of the stochastic model using both policy operators. As you can see, there are no noticeable differences. This does not mean that the MJO does not provide information, but rather that the lack of such information can be compensated for by the storage capacity available in the system's lakes.

In addition to the cost reduction achievable by considering the MJO status information, the possible error in the estimation of future costs is also relevant. This has an impact on the budget forecast and the scheduling of shipments for importing fuel for thermal power plants. Fig.3 shows the covariance between the components of the MJO and the accumulated thermal generation energy for the next 150 days. If you observe that the covariance is increasing approximately in the next 120 days, indicating that the MJO provides information and that an improvement in the estimate of fuel consumption in that horizon of the order of 2.5% is to be expected.

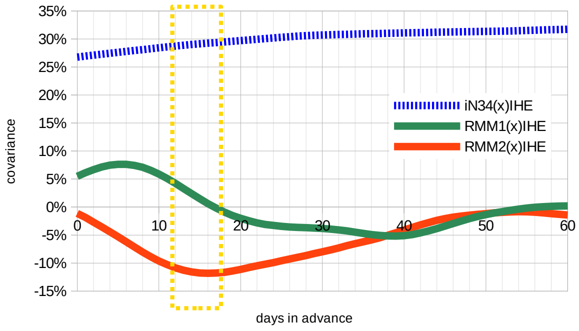

Fig. 1: correlations of iN34 and MJO with incoming hydropower.

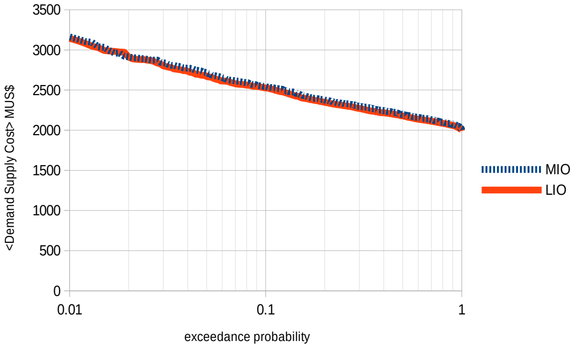

Fig. 2: Electrical energy demand supply cost vs. probability of excess

Conclusions

Although the work carried out is considered a first approximation of incorporating the information provided by the MJO in the programming of Uruguay's energy dispatch, it can be concluded that said information does not lead to a significant reduction in the expected cost of the operation nor does it significantly change the distribution of said cost. This is because the storage capacity available in the reservoirs is capable of compensating for forecast errors in influent flows in periods of 10 to 20 days.

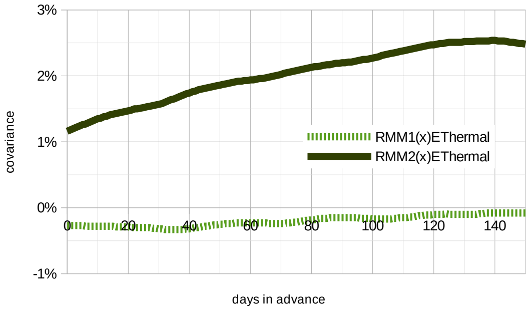

Fig. 3: Correlations between the MJO components and the acumulated thermal energy consumed in the next 150 days

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