A new model for forecasting hourly solar radiation

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Data

- The global solar radiation data we use in the development is from Mildura in South Australia during the year 2000. We have 8760 (24×365) hourly global radiation values in total.

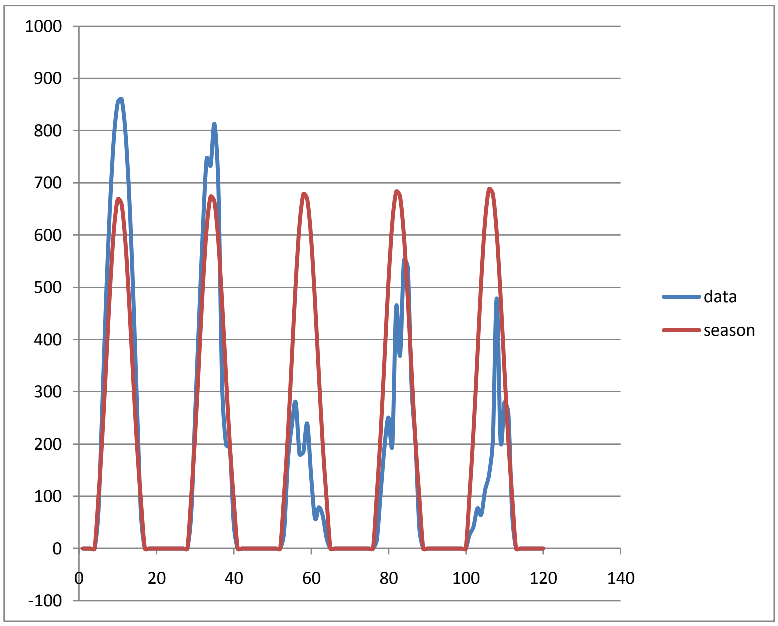
Seasonality

- The first step is to identify and model the seasonality. We have identified several significant cycles using spectral analysis. Fourier series will be used in this step.

$$\begin{aligned} S_t &= \alpha_0 + \alpha_1 \times \cos\frac{2\pi t}{8760} + \beta_1 \times \sin\frac{2\pi t}{8760} + \\ &\quad \alpha_2 \times \cos\frac{4\pi t}{8760} + \beta_2 \times \sin\frac{4\pi t}{8760} + \\ &\quad \sum_{i=3}^{11}\sum_{n=1}^{3}\sum_{m=-1}^{1}[\alpha_i \times \cos\frac{2\pi(365n+m)t}{8760} + \\ &\quad \beta_i \times \sin\frac{2\pi(365n+m)t}{8760}] \end{aligned}$$

  here S_t is seasonal component.

Fourier series and Solar radiation data



Deseasoned data

$$F_t - S_t = R_t$$

- Here F_t is data, R_t is deseasoned data.
- The standard approach is to model the deseasoned data with a second order autoregressive process AR(2) model.

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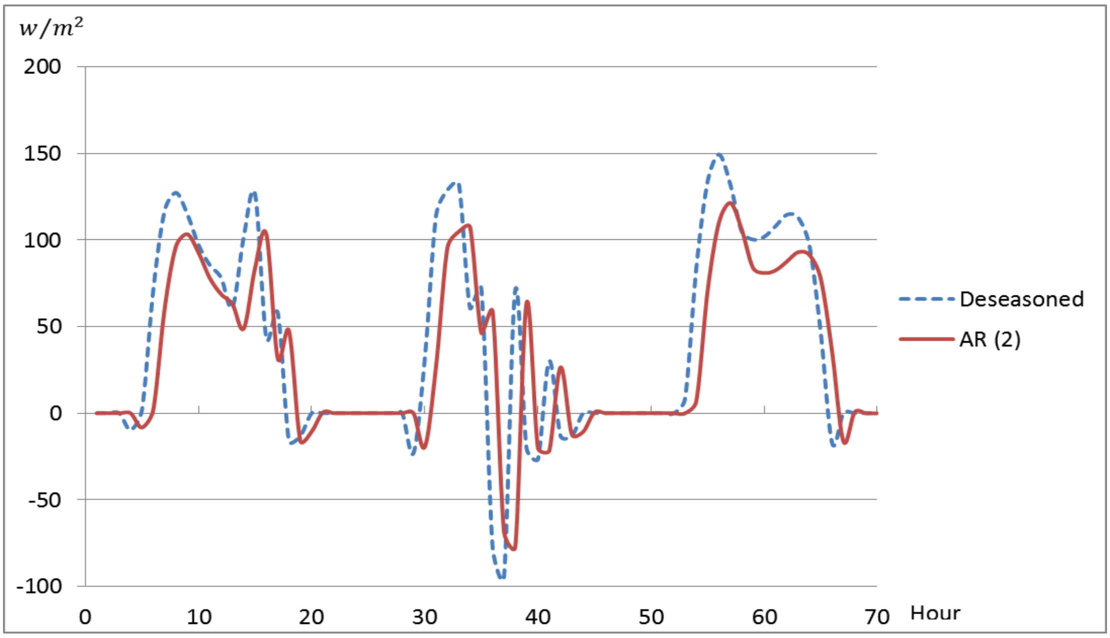
For three days AR(2)



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A Resonation model

- This model is developed by Lucheroni, so here termed Lucheroni model.

$$
\begin{aligned}
R_{t+1} &= R_t + z_t \Delta t + a_t \\
z_{t+1} &= z_t + [\kappa(z_t + R_t) - \lambda(3R_t^2 z_t + R_t^3) \\
&\quad -\varepsilon z_t - \gamma R_t - b] \cdot \frac{\Delta t}{\varepsilon} + \alpha_t
\end{aligned}
$$

here, κ, γ, λ, ε, b, are all coefficients.

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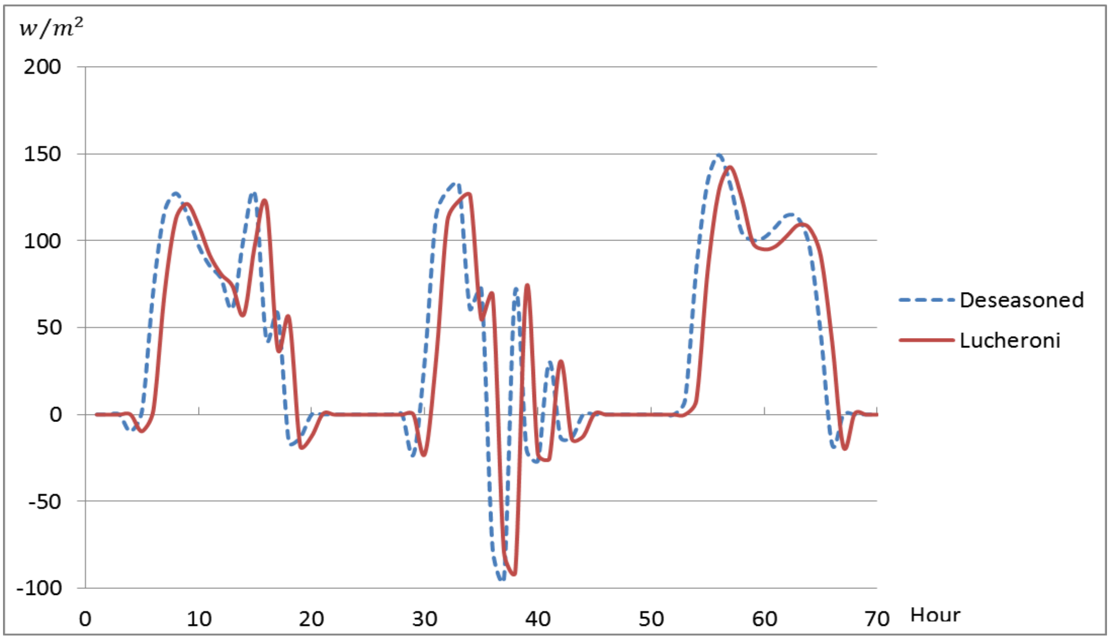
For three days Lucheroni model



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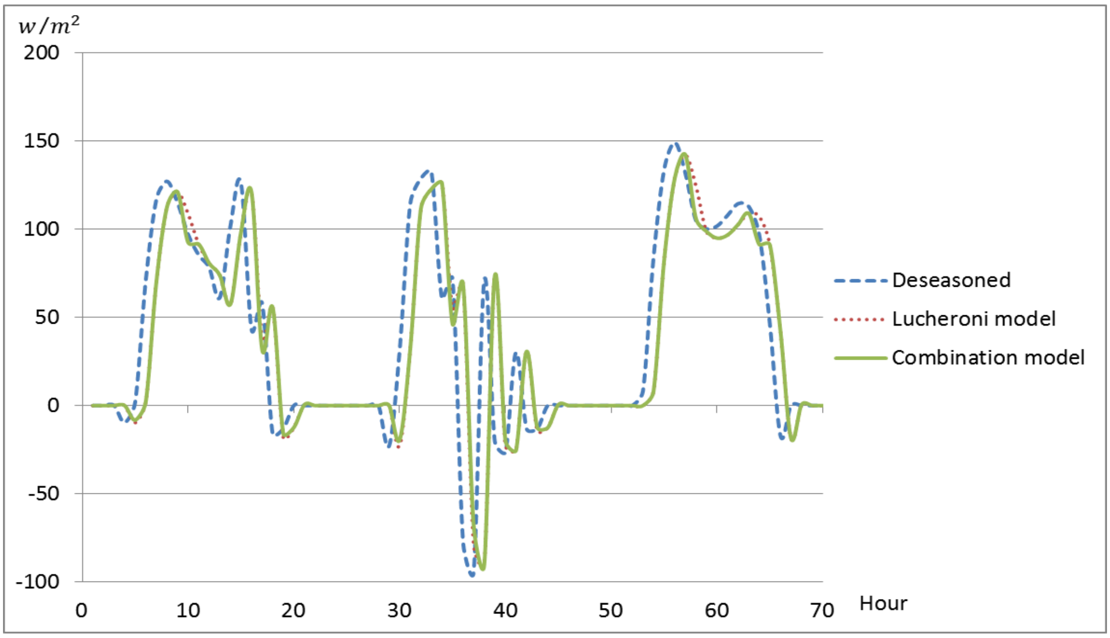
- From those two models, we can see that Lucheroni model is good at pick up the peak and AR(2) model is good at the forecasting in regions of the series, because when the AR(2) model reach the peak, it is converging faster than Lucheroni model.
- To combine the AR(2) model with Lucheroni model could solve those problems.

How to make two models together

- The Lucheroni model reach the peak very well, so when the data increasing we use the Lucheroni model and when the data decreasing change to the AR(2) model which can reduce the error between the data and the model.
- To be more specific,
  By using the data $R_t - R_{t-1}$ to decide which model we should choose in time $t+1$.
  If $R_t - R_{t-1}$ is positive, we choose Lucheroni model.
  If $R_t - R_{t-1}$ is negative, we choose AR(2) model. But when $R_{t-1} - R_{t-2}$ also is negative, we switch back to Lucheroni model. Thus, we take into account a proxy for the curvature by considering what is happening over three time steps.

The combination of AR(2) and Lucheroni



Error analysis for these three models

	Lucheroni+Seasonal	AR+Seasonal	CLA+S
MeAPE	12.01%	11.4%	11.31%
MBE	-0.59	-0.95	-0.62
KSI	25.18%	45.15%	27.50%
RMSAPE	19.09%	18.59%	18.92%
RMSMPE	8.14%	7.93%	8.07%

A new model for forecasting solar radiation

- For applying new model, first of all we need introduce a new component f_t.
- To find the f_t, we need follow these steps,
  The first step difference
  $$R_{t-1} - R_{t-2} = \bigtriangledown^1_{t-1}$$
  Here, $\bigtriangledown^1_{t-1}$ is the first step difference at time $t-1$.
  $$M_t + \bigtriangledown^1_{t-1} = f_t$$
  Here f_t termed fixed component, M_t is the any one of these three models.

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The rules of using f_t

- When the fixed component is increasing which is $f_t - f_{t-1} > 0$.
  1. The fixed component must be continuously increasing which means that the first difference of fixed component is increasing for at least two time steps, e.g. $f_{t-1} - f_{t-2} > 0$ and $f_t - f_{t-1} > 0$.
  2. The first continuous increasing point at time t is dependent on the difference at time $t-1$ which is $R_{t-1} - R_{t-2}$. If it is positive, the fixed component will be valuable which means we can use f_t to replace M_t. Otherwise M_t will not be changed.
  3. The last continuous point f_t is defined by the model M_{t+1}. If $M_{t+1} - M_t$ is negative, we will still use M_t rather than f_t.
  4. Between the first and last point, all M_t should be replaced by f_t.

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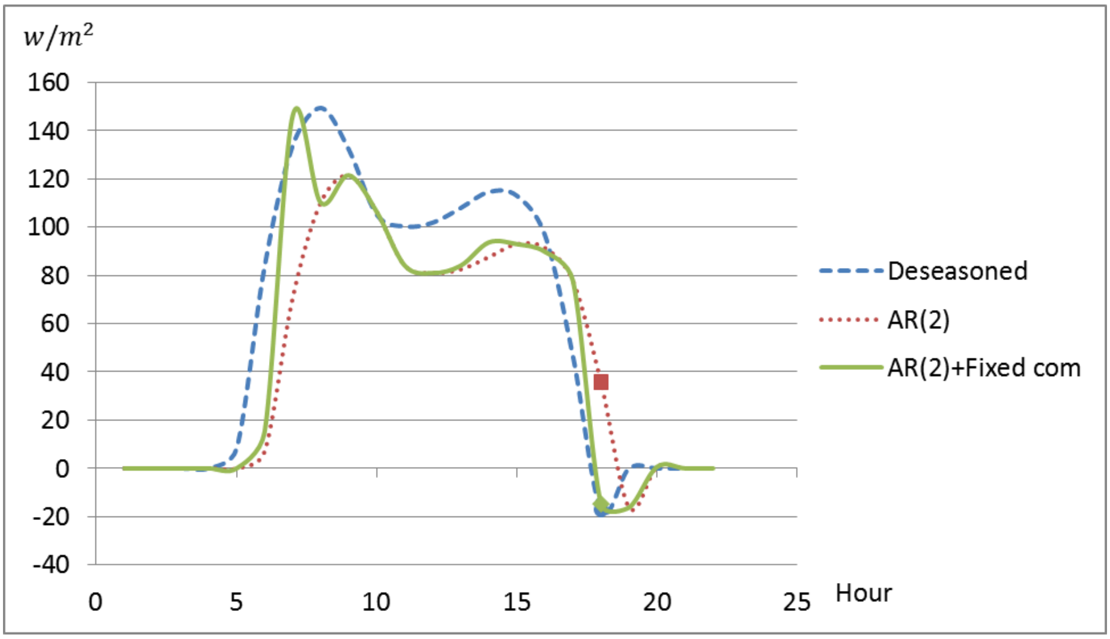
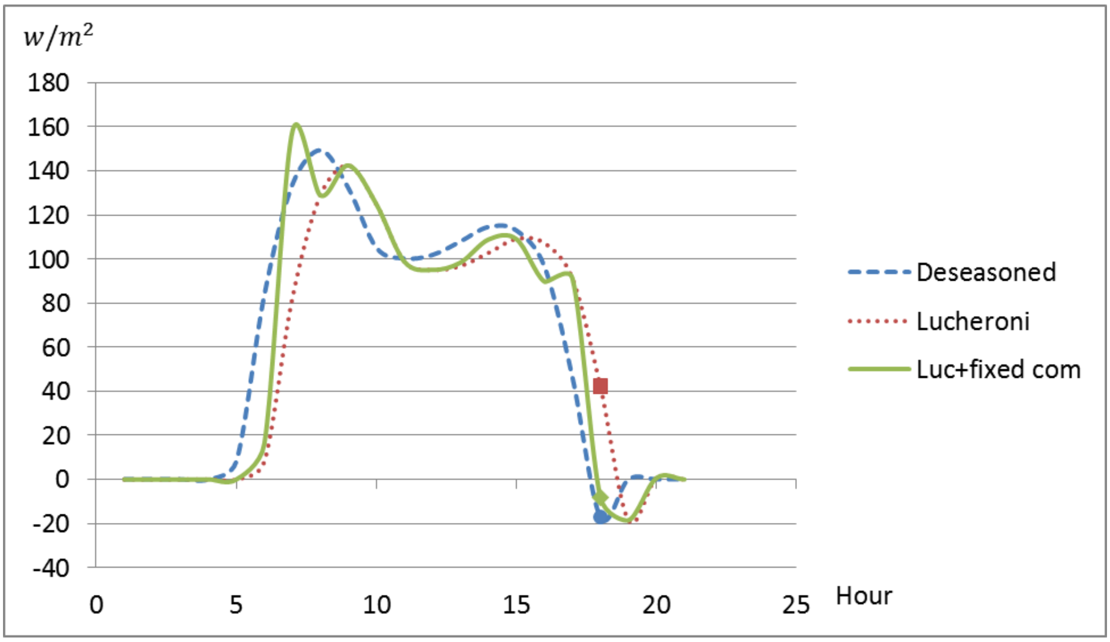
- When the fixed component is decreasing which is $f_t - f_{t-1} < 0$.
  1. The fixed component must be continuously decreasing which means that the first difference of fixed component is decreasing for at least two time steps, e.g. $f_{t-1} - f_{t-2} < 0$ and $f_t - f_{t-1} < 0$.
  2. The first continuous decreasing point at time t is dependent on the difference at time $t-1$ which is $R_{t-1} - R_{t-2}$. If it is negative, the fixed component will be valuable which means we can use f_t to replace M_t. Otherwise M_t will not be changed.
  3. The last continuous decreasing point f_t is defined by the model M_{t+1}. If $M_{t+1} - M_t$ is positive, we will still use M_t rather than f_t.
  4. Between the first and last point, all the points depend on the previous difference. The absolute value of the previous difference must be over a number $\hat{A}$. Here, $\hat{A}$ is decided by the 10th percentile of all middle points of previous differences for a year. (For example, for the year 2000 data, $\hat{A}$ is 15.395 and $\hat{A}$ for the year of 2001 data is 15.196. However, using 15.395 as target instead of 15.196, it does not affect the result at all.)

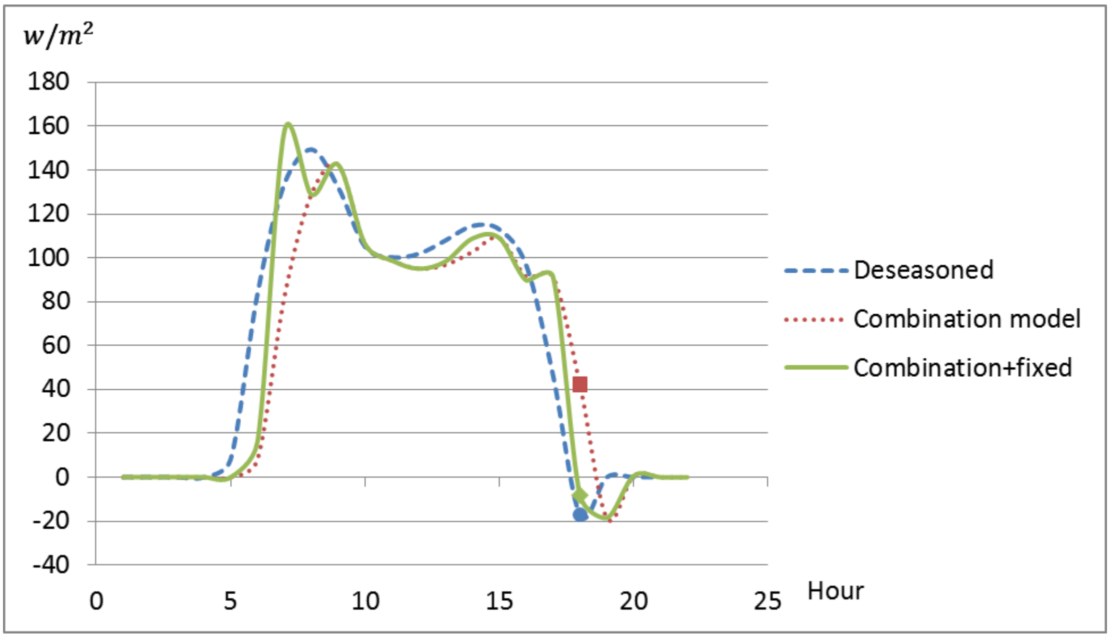
when the fixed component replaces some of the predictions in the AR(2) model



when the fixed component replaces some of the predictions in the Lucheroni model



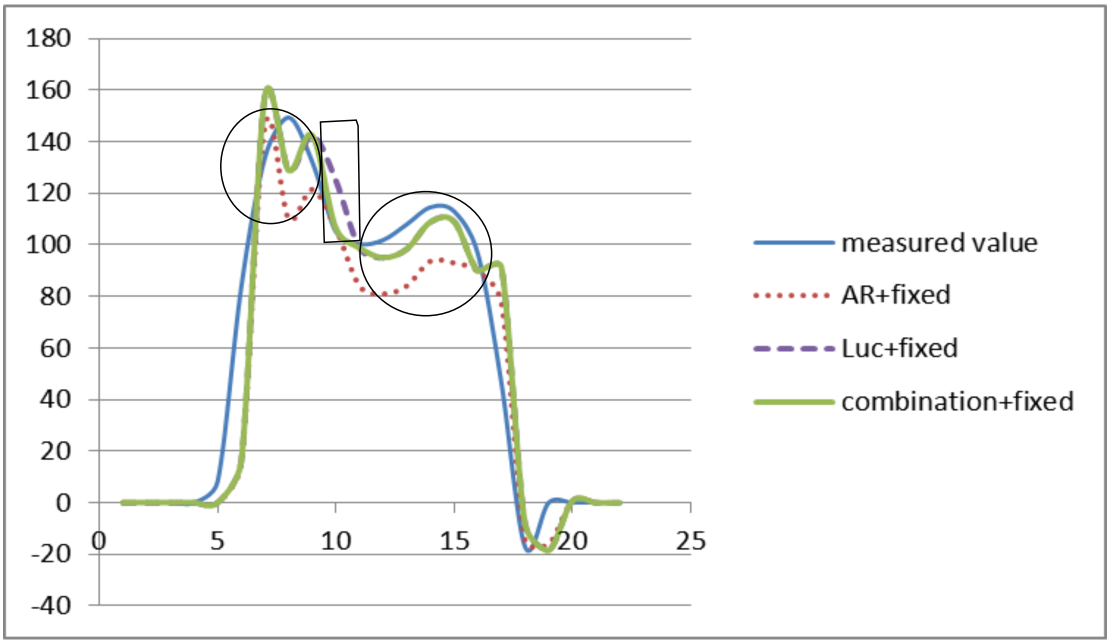
when the fixed component replaces some of the predictions in the combination model



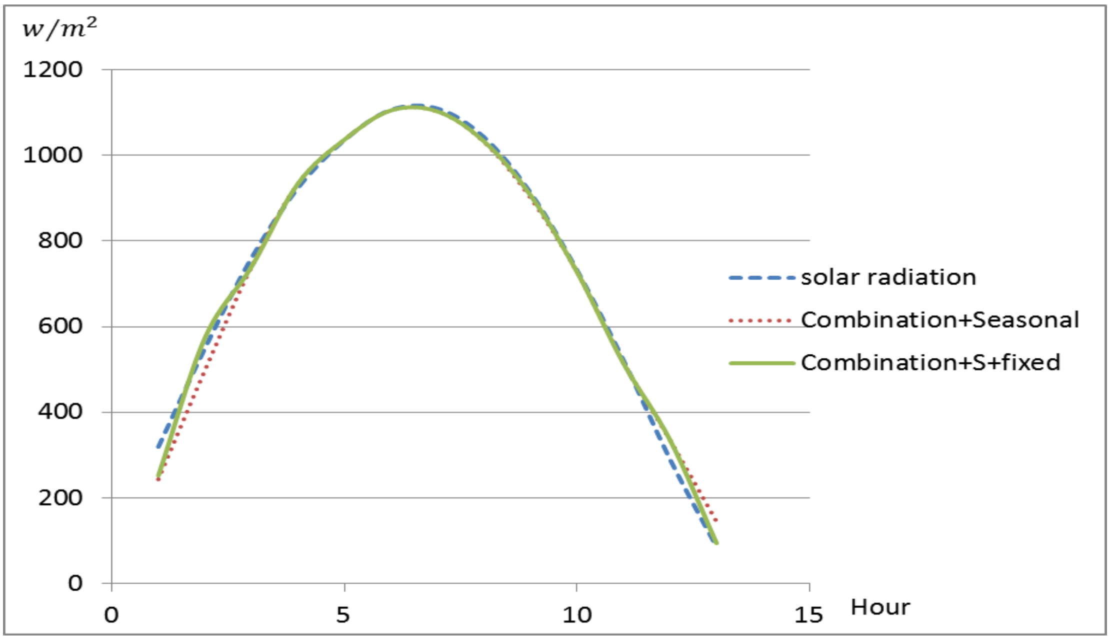
Error analysis for these three models with f_t

	Luc(F)+S	AR(F)+S	CLA(F)+S
MeAPE	7.51%	7.46%	7.53%
MBE	0.04	0.16	0.45
KSI	16.53%	32.31%	17.92%
RMSAPE	16.73%	16.20%	16.50%
RMSMPE	7.13%	6.91%	7.04%

Comparison of AR(2) model with fixed component and combination model with fixed component



First day, a very clear day on the 4th of January 2000, Mildura



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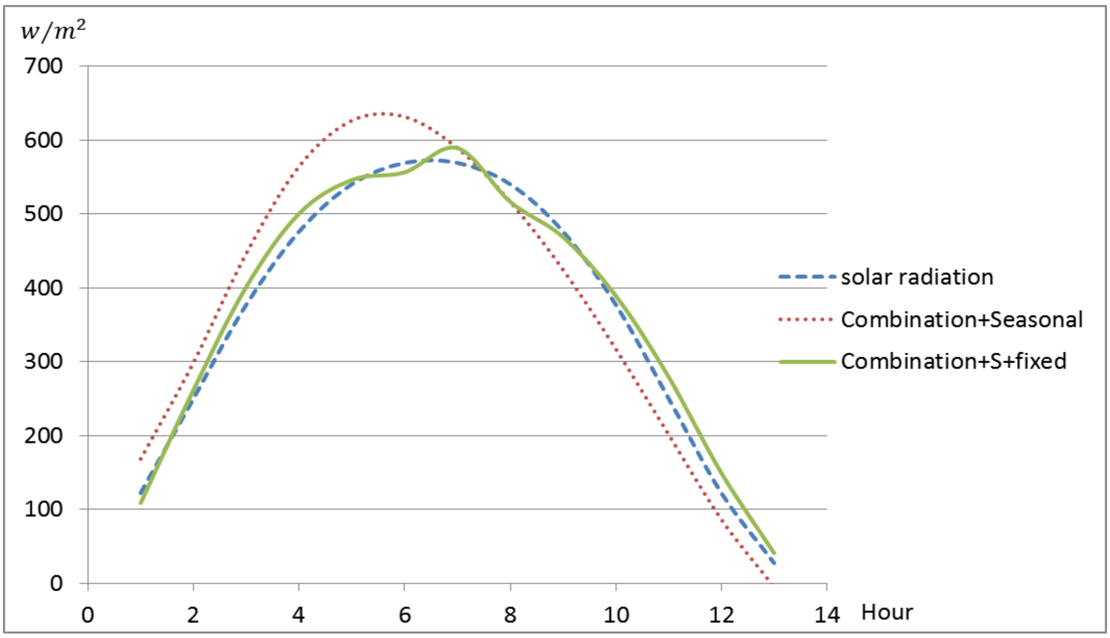
Second day, an overcast day, but with no obvious clouds blocking the sun on the 24th of January 2000, Mildura



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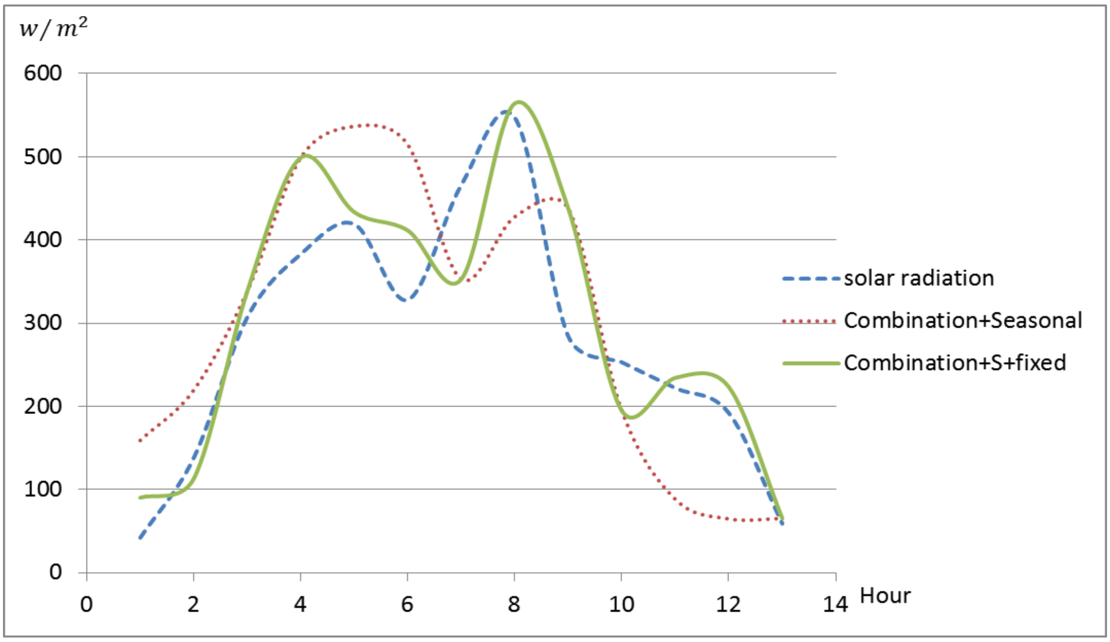
Third day, the following day, 25th of January 2000, which was an overcast day with clouds blocking the sun intermittently.



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Future work

- In the future, prediction accuracy of the proposed model can be further tested using global solar radiation data on different time scales and for different locations, as well as applied to other types of data, such as wind energy data.

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- Thank you for your time.