

Deep learning in geodesy

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Abstract

Deep learning (DL) can be a way to automate the analysis of predictions. DL algorithms are in the hierarchy of increasing complexity and abstraction while traditional machine learning is linear. In this study, the downscaling of the GRACE-FO satellite was investigated using a convolutional neural network (CNN). Three solutions were used for downscaling with CNN. Down-scaling accuracy is estimated to be 0.1 degree and its absolute error is 1 mm. The results show that this method can improve the GRACE-FO spatial resolution problem with higher efficiency and make it easier to analyze the results. Also, DL can solve many geodesy problems.

Keywords: Deep learning, Geodesy, GRACE-FO, Down scaling, CNN

Introduction

Deep learning is a type of machine learning and artificial intelligence that mimics the way the human mind uses to learn a particular subject. This type of learning is one of the important elements in data science, which includes statistics and forecasting modeling [1]. DL is very useful for data scientists who are tasked with collecting, analyzing and interpreting large amounts of data, making this process faster and easier. In a way, it can be said that DL is the same as machine learning, in that at the level of complex tasks, representation or abstraction, it does learning for the machine, and in this way, the machine finds a better understanding of existential realities and can identify different patterns. At the simplest level, DL can be a way to automate the analysis of predictions. DL algorithms are in the hierarchy of

increasing complexity and abstraction while traditional machine learning is linear [2].

In this research, the applications of deep learning in geodesy are discussed. DL can be used in GRACE signal reconstruction to the problem of signal attenuation. Waveform retracking altimetry can also be implemented with CNN, which has achieved high accuracy. To determine the geoid, back propagation networks have been used, which has increased the spatial resolution of the geoid. The combination of DL and wavelet can also be useful in geodetic problems [3-15].

Convolutional neural network

The CNN, like other neural networks e.g., the multi-layer perceptron (MLP) neural network, is composed of weighted and biased neural layers with the ability to learn. The following steps are taken in CNN:

- 1-Neurons receive input sets.
- 2-Internal multiplication is done between the weights of the neurons and the inputs.
- 3-The result is added by bias.
- 4-Finally, a nonlinear function (the same as the activation function) is passed [1].

The above process is done layer by layer and finally, we reach the output layer. The output layer generates the network forecast. But with so many similarities between MLP and CNN. The difference is in the input, for example, images are usually displayed as a two-dimensional matrix of numbers. Each drive in this 2D matrix is equivalent to one pixel. If we have a 100×100 image size, we have 10,000 pixels sitting peacefully next to each other in two dimensions. We want to create an input layer for this 10,000 pixels; We need to consider 10,000 neurons for the input layer of the MLP network. Adding more neurons and layers to this MLP network allows our network to include a large volume of parameters, its computations to be costly, and of course overfitting to occur [2]. But the CNN does not change the structure of the input and pays attention to the connection between neighboring pixels.

Results

In this study, to increase the spatial resolution of GRACE-FO [3,4], CNN in DL has been used. The study area of Iran has been selected. Figure 1 shows the total water storage (TWS) 1-degree solutions of CSR, GFZ, and JPL with their differences on

June 1, 2018. Negative TWS is observed in the Central and Southern Caspian parts [10]. The difference between the different solutions reaches a maximum of 0.02 m.

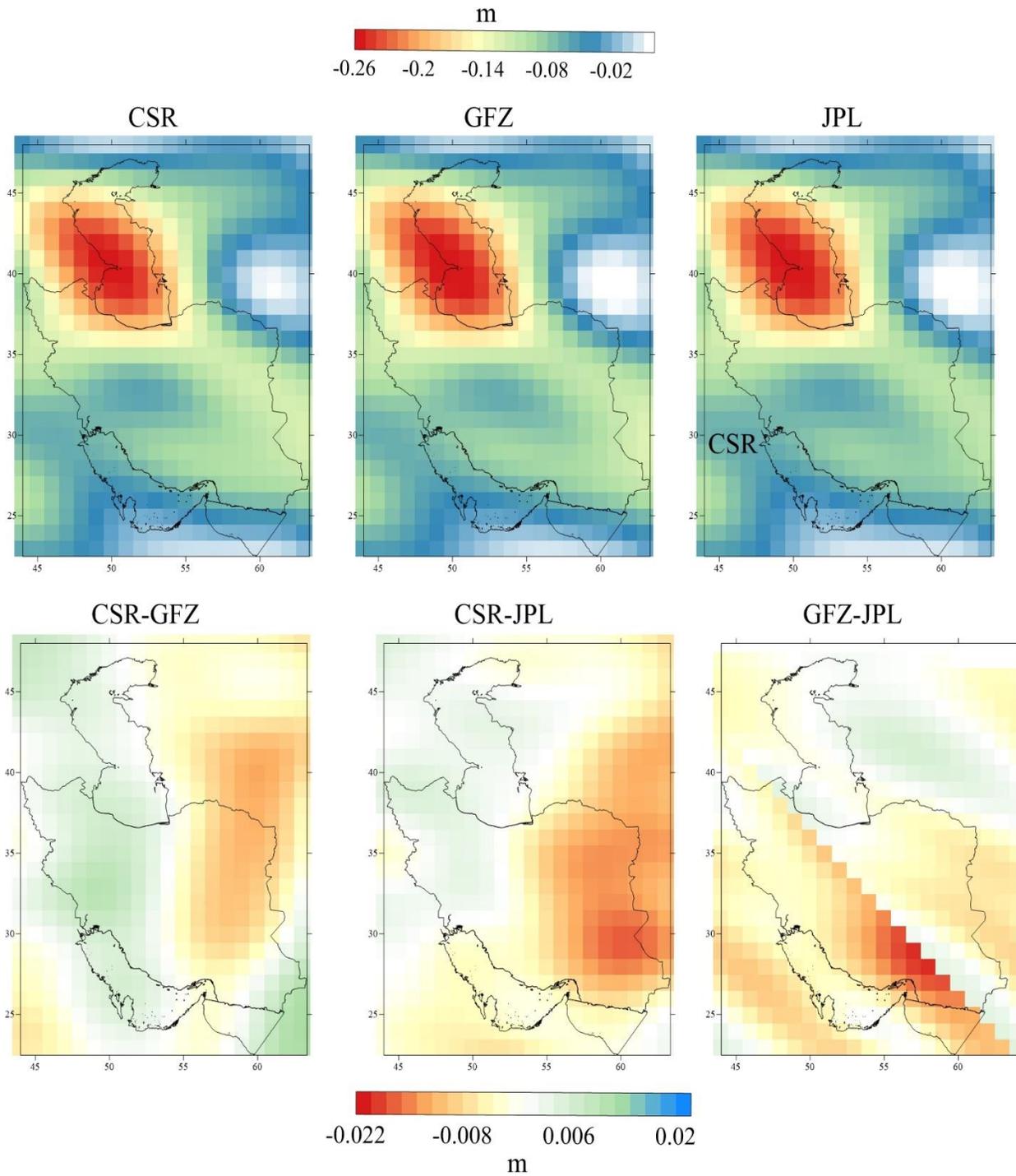


Figure 1. TWS 1-degree solutions of CSR, GFZ and JPL with their differences on June 1, 2018

CNN is used to increase spatial resolution and downscaling, as shown in Figure 2. Three solutions were used for downscaling with CNN. Down-scaling accuracy is estimated to be 0.1 degree and its absolute error is 1 mm.

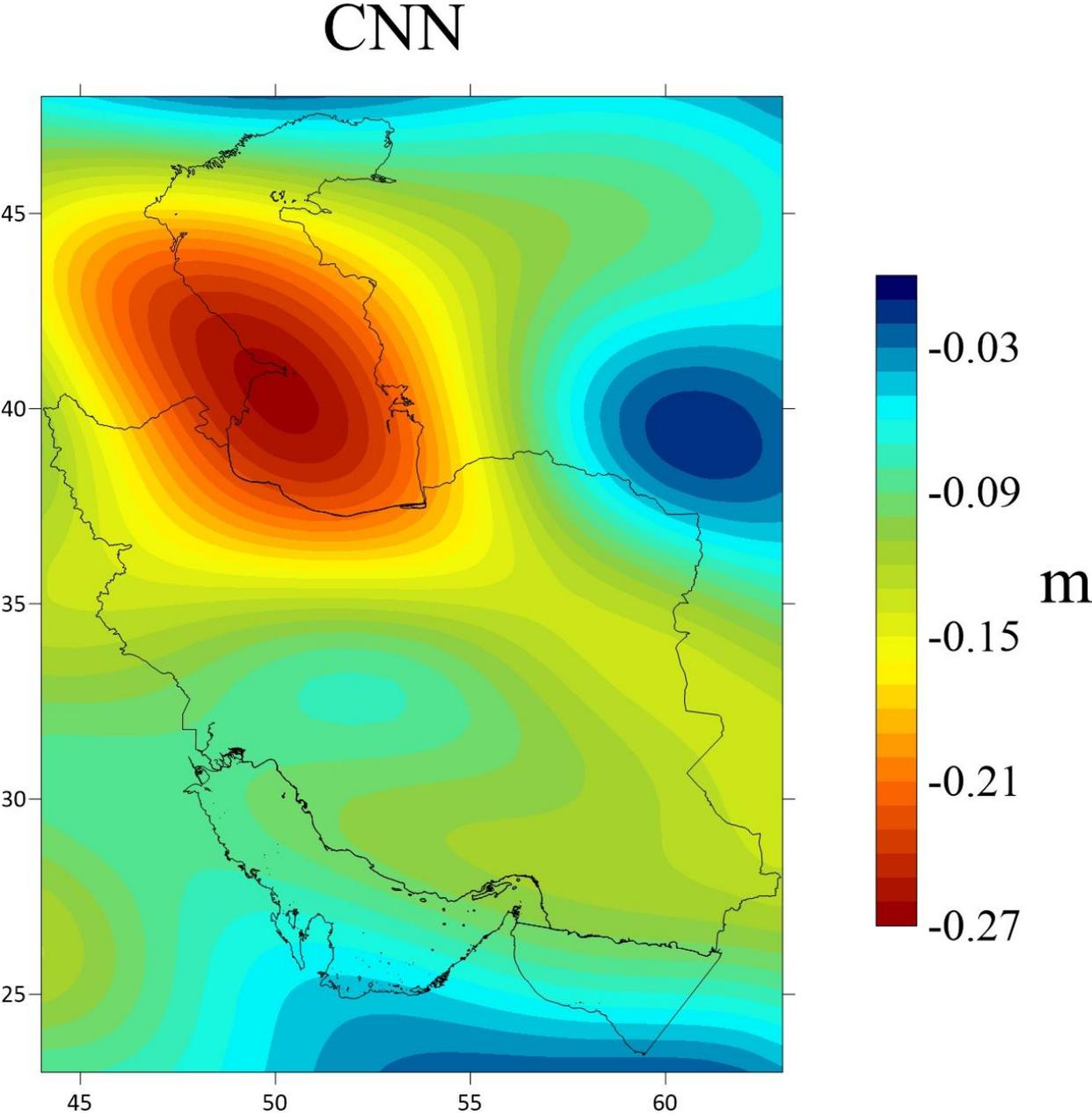


Figure 2. CNN output on June 1, 2018

Conclusion

In this study, the downscaling of the GRACE-FO satellite was investigated using CNN. Three solutions were used for downscaling with CNN. Down-scaling accuracy is estimated to be 0.1 degree and its absolute error is 1 mm. The results show that this method can improve the GRACE-FO spatial resolution problem with higher efficiency. DL can solve many geodetic problems [5, 9, 10, 11, 13, 14].

Competing interests:

The authors declare no competing interests.

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