*"**Importance of spatial and depth-dependent drivers in groundwater level modeling through machine learning**" by Pragnaditya Malakar, Abhijit Mukherjee, Soumendra N. Bhanja, Dipankar Saha, Ranjan Kumar Ray, Sudeshna Sarkar, Anwar Zahid*

<u>Prof. Saman Javadi's Comment:</u>

The authors have investigated the relative influence of major drivers in groundwater level change and linked them with the performance of machine learning-based predictive models, in a very important transboundary system. The study illustrates the advantages and limitations of machine learning-based modeling in a very heterogeneous regime. Due to this specific study area, this study is particularly important. The spatial and depth-dependent variability in model performance using GWL data is novel. The depth component of the study is particularly impressive, and probably first of its kind. In my view, the manuscript should be accepted with minor revision. The manuscript is well written, well-segmented and concise. However, there are some typos that should be corrected.

Reply: We thank Prof. Saman Javadi for his review and support for the general intent of the paper. The comments are very helpful and used to improve the manuscript while addressing them.

Highlights of the revision:

We have

a) Added a brief discussion on the major drivers of groundwater level change
b) Moved the flowchart to the main text
c) Described the hydrogeological conditions and aquifer characteristics and two maps added in this regard
d) Added the full forms of the abbreviation used in Figure 6
e) Explained the abbreviations in Table 1

SC2. Comment 1: If possible please add few lines on major drivers in the introduction section, importantly for the abstracted part of the aquifer.

Reply: We thank Prof. Javadi for the comment. Following Prof. Javadi's comment, we have added a brief description of major drivers on groundwater storage change.

We added,

"There are disagreements in the researcher community on the major drivers influencing groundwater storage change over South Asia. Some studies have highlighted the significant relation between groundwater storage change and precipitations (Asoka et al., 2017, 2018). Other studies (Mukherjee et al., 2007; MacDonald et al., 2016; MacDonald et al., 2015; Bhanja et al., 2017a; Lapworth et al., 2018; Bhanja et al., 2019a; Bhanja et al., 2020) have indicated that groundwater abstraction (through influencing recharge, irrigation return flow) is the primary factor in groundwater storage change in the region."

Reference

Asoka, A., Gleeson, T., Wada, Y. and Mishra, V.: Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India, Nat. Geosci., 10(2), 109–117, doi:10.1038/ngeo2869, 2017.

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Bhanja, S. N., Mukherjee, A., Rodell, M., Wada, Y., Chattopadhyay, S., Velicogna, I., Pangaluru, K. and Famiglietti, J. S.: Groundwater rejuvenation in parts of India influenced by water-policy change implementation, Sci. Rep., 7(1), 7453, doi:10.1038/s41598-017-07058-2, 2017a.

Bhanja, S. N., Mukherjee, A., Rangarajan, R., Scanlon, B. R., Malakar, P. and Verma, S.: Long-term groundwater recharge rates across India by in situ measurements, Hydrol. Earth Syst. Sci., 23(2), 711–722, doi:10.5194/hess-23-711-2019, 2019a.

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Lapworth, D. J., Zahid, A., Taylor, R. G., Burgess, W. G., Shamsudduha, M., Ahmed, K. M., Mukherjee, A., Gooddy, D. C., Chatterjee, D. and MacDonald, A. M.: Security of Deep Groundwater in the Coastal Bengal Basin Revealed by Tracers, Geophys. Res. Lett., 45(16), 8241–8252, doi:10.1029/2018GL078640, 2018.

SC2. Comment 2: It would be better if the flow chart is moved into the main article from the supplementary section.

Reply: Thank you, Prof. Javadi, for the comment. Following your comment, we have moved the flow chart in the main text.

SC2. Comment 3: The Geology and hydrology of the study area could be expanded a little more.

Reply: We thank the reviewer for his/her comment. The IGBM basin exhibits a wide range of permeability, transmissibility, hydraulic conductivity, and aquifer depth. The diverse depositional settings and environment of Pleistocene to Holocene sediments resulted in variable aquifer properties across the basin. Following the reviewer's suggestions, we have added a brief description of the hydrogeological conditions and aquifer characteristics of the IGBM. Furthermore, we also added two figures showing the aquifer type, horizontal hydraulic conductivity, transmissivity, and specific yield of India and Bangladesh. We added,

"*The sediment (both recent Plio-Pleistocene to Holocene alluvium and older Miocene rocks) thickness of IGBM is up to 2 km (Singh et al., 1996). However, the effective thickness of the aquifer in most of the IGBM is generally the top 200 m. Notably, in the Bengal basin area in the eastern part of the Ganges basin and the Indus basin area, the effective aquifer thickness could be more than 300 m (Mukherjee et al., 2007; Macdonald et al., 2015). The diverse depositional setting and environment of Pleistocene to Holocene sediments resulted in variable aquifer properties across the basin (Bonsor et al., 2017). A distinct systematic reduction in permeability is found away from the mountain and towards the coast in most of the IGBM; however, the distribution is more* *complex for the Ganges basin (Macdonald et al., 2015). The transmissivity within the upper and middle Ganges basin and most of the Brahmaputra basin ranges from several 100 $m^2 day^{-1}$ to more than 5000 $m^2 day^{-1}$ (Bonsor et al., 2017), which is representative of permeability values of 5 – 100 m/d (CGWB 2010). However, in the Indus basin, the permeability values of <10 $m{\cdot}day^{-1}$ to >60m $m^2 day^{-1}$ is reported. Fig. S1 show the aquifer type, horizontal hydraulic conductivity, and transmissivity of India and Bangladesh (Bhanja et al., 2017a, 2019a). The specific yield in the unconsolidated sedimentary (high hydraulic conductivity) aquifer part of the IGBM ranges from 0.06 to 0.20 (mean 0.013). However, the specific yield values up to 0.08 are reported in the consolidated sedimentary (medium hydraulic conductivity) part of the basin (Bhanja et al., 2016). A specific yield map for India and Bangladesh is shown in Fig. S2.*"

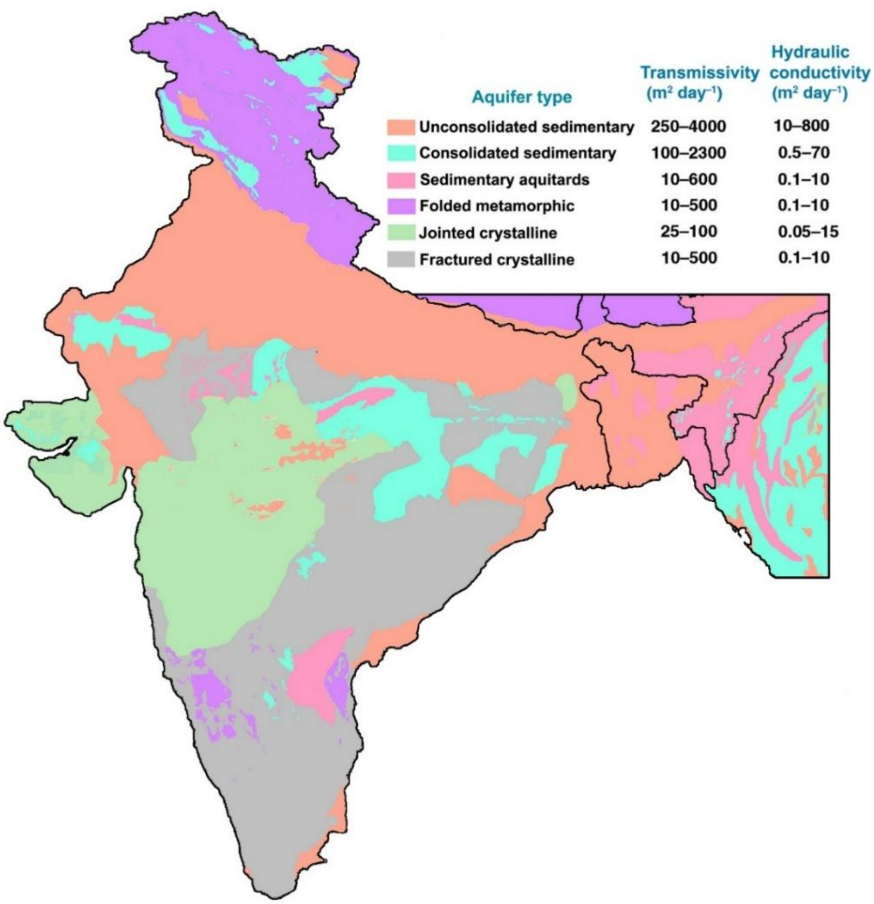
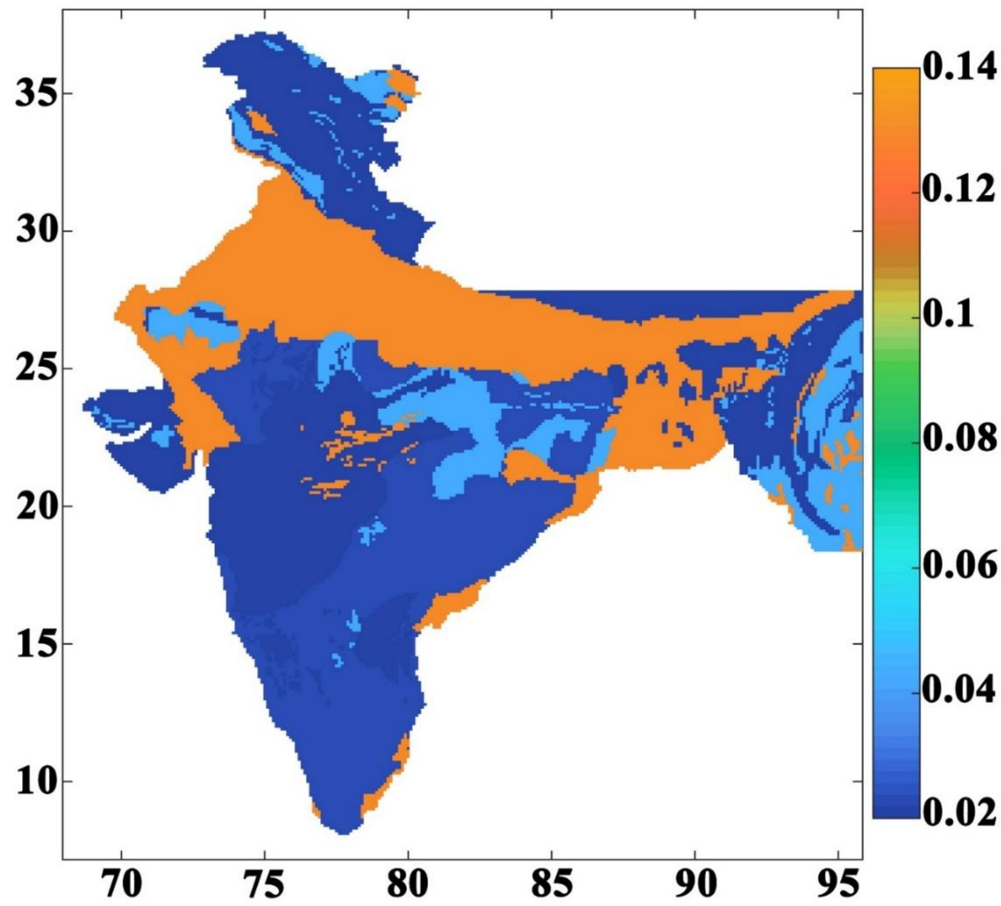


Fig. S1. Different aquifer types, horizontal hydraulic conductivity ($mday^{-1}$) and transmissivity ($m^2 day^{-1}$) for India and Bangladesh (modified from Bhanja et al., 2019a).



"Fig. S2. Specific yield map for India and Bangladesh (modified from Bhanja et al., 2016)."

Reference

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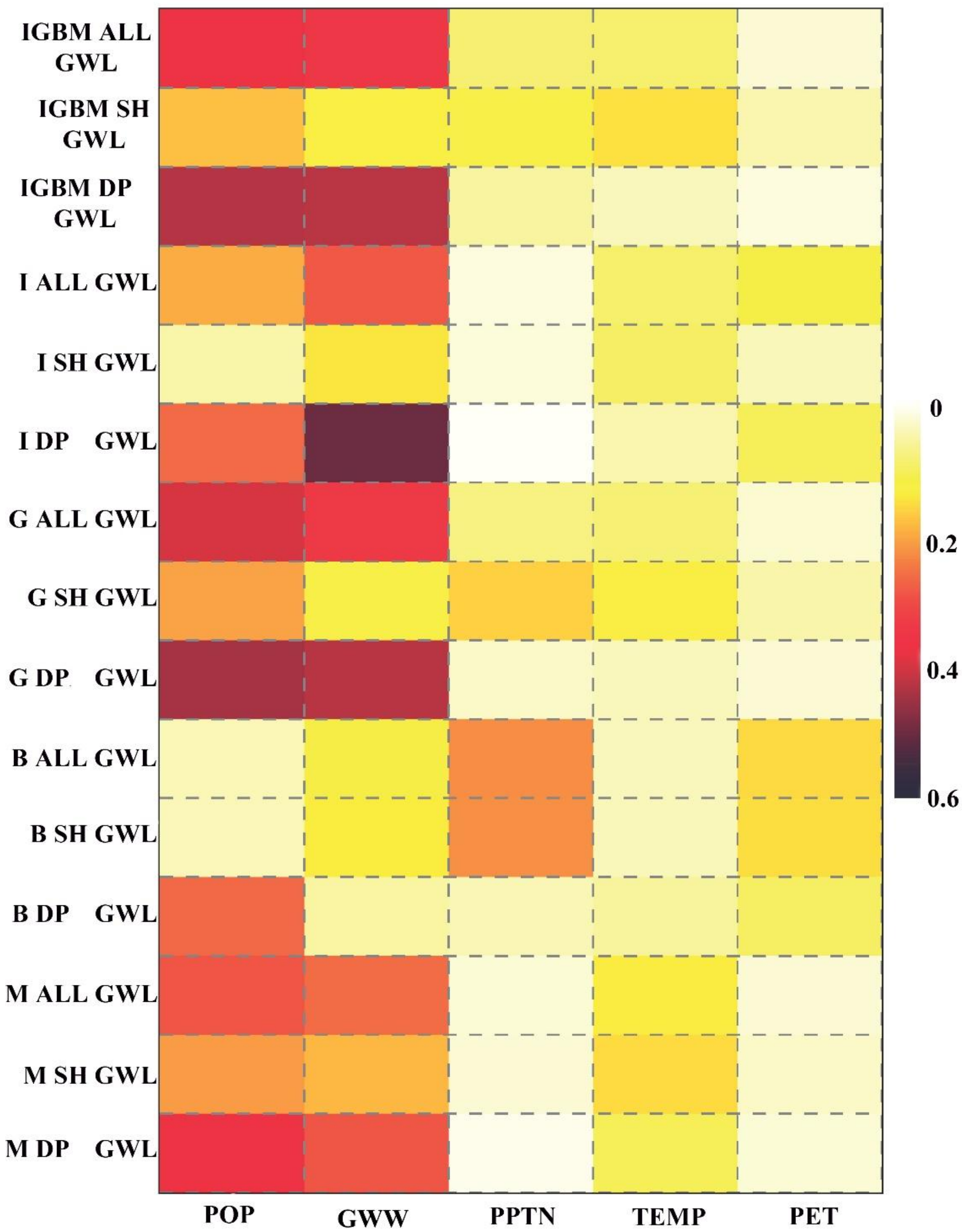
Mukherjee, A., Fryar, A. E. and Howell, P. D.: Regional hydrostratigraphy and groundwater flow modeling in the arsenic-affected areas of the western Bengal basin, West Bengal, India, Hydrogeol. J., 15(7), 1397–1418, doi:10.1007/s10040-007-0208-7, 2007.

Singh, I.B.: Geological evolution of Ganga Plain: an overview. J Palaeontol Soc India 41:99–137, 1996

SC2. Comment 4: In Figure 6 please mention the full form of the abbreviation used, at least in the figure captions.

Reply: We thank the reviewer for the comment.

We have added the full forms of the abbreviation used.



"Figure 6. The relative contribution of the predictor variables on groundwater level variation, determined by the dominance analysis.

Abbreviations: IGBM, Indus-Ganges-Brahmaputra basin; I, Indus basin; G, Ganges basin; B, Brahmaputra basin; M, Meghna basin; ALL, all observation wells; SH, Shallow observation wells; DP, deeper observation wells; GWL, groundwater level; POP, population; GWW, groundwater withdrawals; PPTN, precipitation; TEMP, temperature; PET, potential evapotranspiration."

SC2. Comment 5: In the ANN, SVM table (Table 1) the author should explain in short Model A, B, C.

Reply: The author would like to thank Prof. Javadi for the comment.

"Abbreviations: ALL, all observation wells; SH, Shallow observation wells; DP, deeper observation wells; GWL, groundwater level; Model A, GWL as input; Model B, GWL + meteorological variables as input; Model C: meteorological variables as input."