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Hydrology and Earth System Sciences Discussions

Interactive comment on "Recent trends in groundwater levels in a highly seasonal hydrological system: the Ganges-Brahmaputra-Meghna Delta" *by* M. Shamsudduha et al.

M. Shamsudduha et al.

m.shamsudduha@ucl.ac.uk

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Reply to comments on "Recent trends in groundwater levels in a highly seasonal hydrological system: the Ganges-Brahmaputra-Meghna Delta by Shamsudduha et al."

M. Shamsudduha, R. E. Chandler, R. G. Taylor, and K. M. Ahmed

Correspondence to: M. Shamsudduha (m.shamsudduha@ucl.ac.uk)

Reply to reviewer's (#2) comments:

We thank the anonymous reviewer for helpful comments on the statistical methods we have applied in our analyses of groundwater level time-series records to assess seasonality and long-term trends. Our replies to the reviewer's comments are provided below:

(1) Page 4127, L19-21: The claim on disadvantage is bias.

Reply: In our paper, L19-21, we assert that traditional trend tests (e.g., Mann-Kendall trend test) are not capable of characterizing trends in the time series. Moreover, trends calculated by parametric methods (e.g., linear trend) are often masked by seasonality and autocorrelation in the time series. Therefore, we apply the seasonal-trend decomposition technique (STL) to highly seasonal time-series of groundwater level records to characterize trends and resolve seasonality and irregular components.

(2) The review is not fully up to date.

Reply: The reviewer has recommended two references (Shao and Campbell, 2002; Genton and Hall, 2007) which deal with the assessment of trends in time-series records with seasonality (periodicity) and change points. We have referred to several studies (see references in section 1: Introduction) which cover a wide range of statistical methods commonly used for trend analysis in time-series, particularly in hydrological sciences. We did not refer to the papers recommended by the anonymous reviewer (#2) since we neither model trends in time series of groundwater levels nor predict future change where the use of covariates or periodic functions can be used.

(3) The setting in model (1) can only decompose a periodic function with fixed amplitude. However, the results in the paper (see Fig. 6) have varying amplitudes (Panel b). Is it based on multiplicative model?

Reply: It is unclear to which model the anonymous reviewer refers. In Fig. 6b we show an example of a STL decomposition resolving seasonality where the amplitude varies. In section 3.4 (Shamsudduha et al., 2009), we explain how the STL method works and

it is not limited to a periodic function of fixed amplitude. We refer to Cleveland et al. (1990) for a more detailed discussion of the STL decomposition procedure.

(4) It is not clear that how the linear trend (Fig. 5) for different percentiles (5% median and 95%) were calculated. Is it by least squares method?

Reply: We have calculated trends in groundwater levels for the dry and wet seasons by fitting linear trend through the 5th and 95th percentiles of groundwater levels for each year from 1985 to 2005. We do not apply quantile regression (Koenker and Bassett, 1978) which models conditional quantiles as functions of predictors to see the effects of extreme distributions of dry- and wet-period groundwater levels on the long-term trends. We have rather calculated the percentiles for each year and used linear regression to assess trends in dry and wet seasons for the entire records.

(5) It is not clear why the paper does try to explore the relationships between rainfall and groundwater levels.

Reply: We thank the reviewer for the recommendation of exploring the relationship between rainfall and groundwater levels in Bangladesh using the HARTT (Hydrograph Analysis - Rainfall and Time Trend) method as recommended in Ferdowsian and Pannell (2001; 2009). This is a focus of our current research as we investigate the impacts of rainfall intensity on groundwater recharge. The recommendations of the anonymous reviewer will be considered in our on-going research together with a range of techniques such as cross-correlations (Lee et al., 2006) and new datasets that include high-frequency (every half hour) observations of rainfall and groundwater levels and estimates of groundwater abstraction for irrigation throughout Bangladesh.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 4125, 2009.