

The Gravel Parameterization Schemes on Tibetan Plateau and Its Assessment Using RegCM4

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- Scientific expeditions have suggested that the gravel is widely distributed over the TP with a rather high content, However, the effect of gravel has not been considered in the mainstream land model currently.
- This study has taken into the effect of gravel account in the regional hydrothermal simulation over the TP.

Introduction

- Scientific expeditions have suggested that the gravel (particle size > 2 mm) is widely distributed over the TP with rather high content, however, the effect of gravel has not been considered in the mainstream land model currently, thus it is difficult to capture the actual soil hydrothermal regimes accurately.
- Some scientists have developed a set of soil hydrothermal parameterization schemes, and the results show that the improvement is significant. But there is a deficiency with respect to these attempt in that the validation is generally carried out at a single site, the regional assessment is absent.

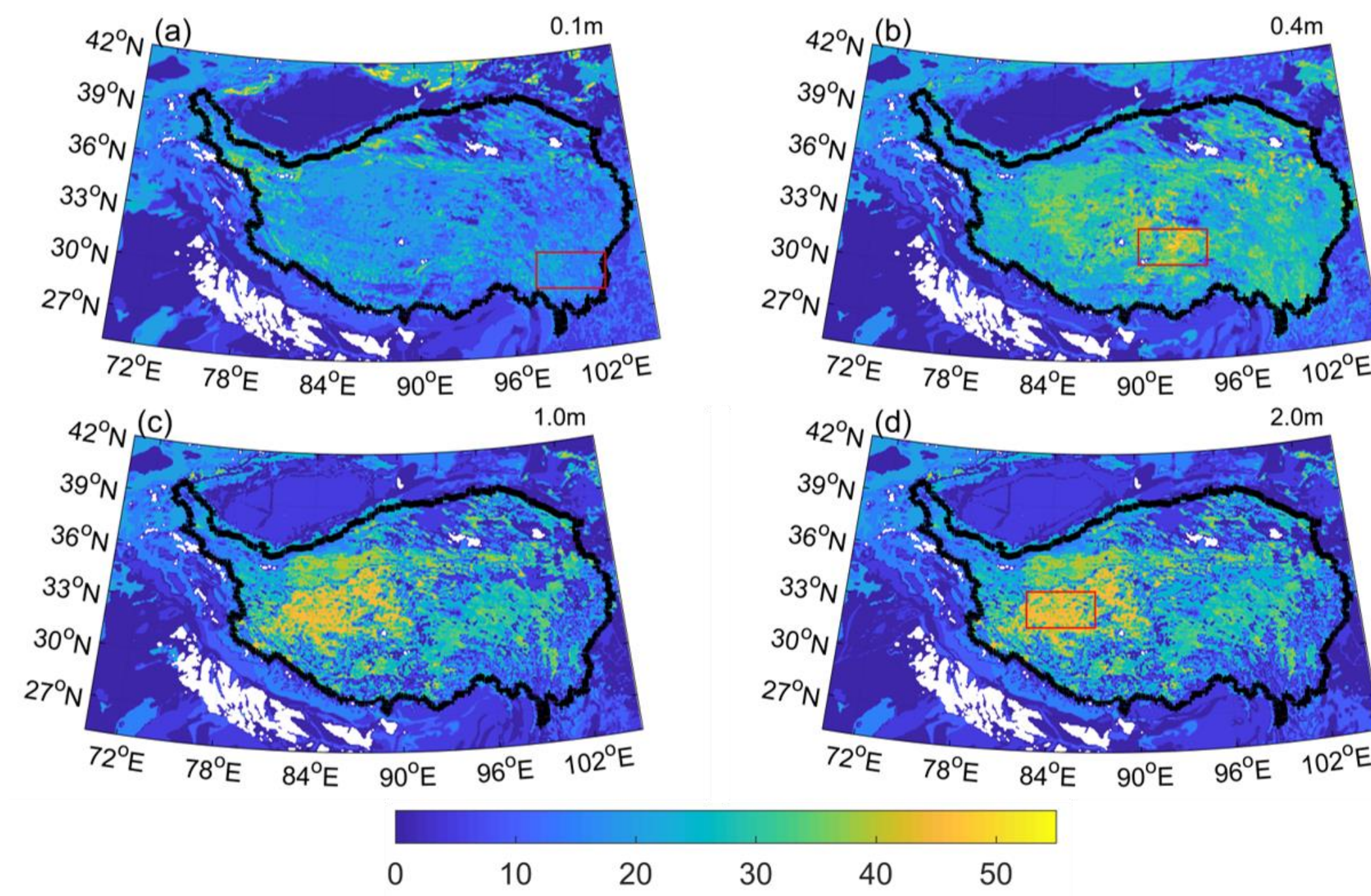


Fig 1. Spatial distribution of gravel content (unit: %) over the TP. Left: 0.4 m. Right: 2.0 m.

- Due to the heterogeneity for distribution of the gravel content, there is a necessity in regional assessment.

Our main works are as follows:

- A gravel dataset applicable to the RegCM4.7 is firstly developed and the pre-processing interface is modified to make the gravel dataset available.
- The original hydrothermal parameterization schemes are replaced by the gravel parameterization schemes.
- Three small areas are selected in terms of the distribution of gravel content to assess the regional simulation effect.

Simulation

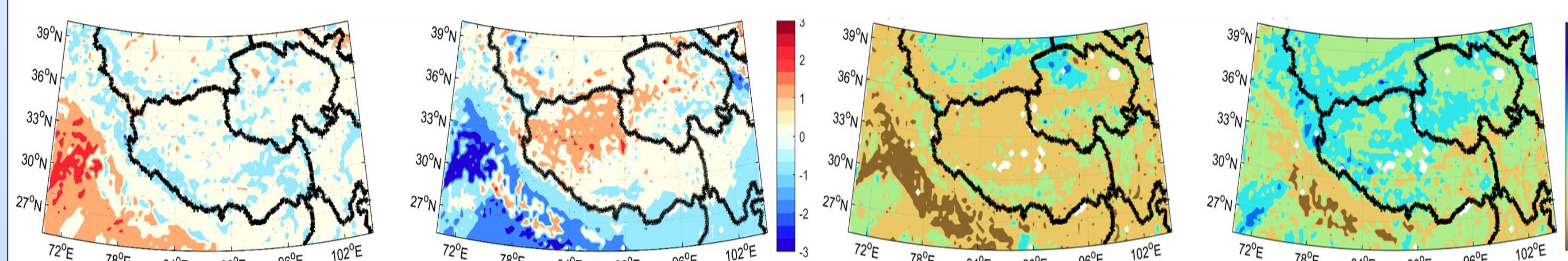


Fig 2. Difference in simulated soil temperature between two schemes. Positive values stand that the temperature from the gravel schemes is higher than that of the original schemes. Left: shallow layers. Right: deep layers.

Fig 3. Difference in simulated soil moisture between two schemes. Positive values stand that the temperature from the gravel schemes is higher than that of the original schemes. Left: shallow layers. Right: deep layers.

- The 6-h EIN15 reanalysis data from the ECMWF are adopted as the initial and boundary data. The gravel content is from the gridded Global Soil Dataset for use in Earth System Models (GSDE) which can download from <http://globalchange.bnu.edu.cn/research/data>.
- The soil temperature simulated by the gravel schemes is generally increased, especially in the western TP where the consequence is much higher than that of the original schemes. The gravel schemes restrict the shallow SM simulated by the original schemes and increase the deep SM in western TP.

Method

	Original schemes	Gravel schemes
The exponent "B" of the mineral soil	$B_{min,i} = 2.91 + 0.159(\% \text{clay})_i$	$B_{min,i} = 2.41 + 0.129(\% \text{clay})_i + 0.06(\% \text{gravel})_i$
The porosity of the mineral soil	$\theta_{sat,min,i} = 0.489 - 0.00126(\% \text{sand})_i$	$\theta_{sat,min,i} = 0.489 - 0.00126(\% \text{sand})_i - 0.004(\% \text{gravel})_i$
The saturated soil matrix potential of the mineral soil	$\Psi_{sat,min,i} = -10.0 \times 10^{1.88-0.0131(\% \text{sand})_i}$	$\Psi_{sat,min,i} = -10.0 \times 10^{1.88-0.0131(\% \text{sand})_i} \times (1 - (\% \text{gravel})_i) + 1.3(\% \text{gravel})_i$
The saturated hydraulic conductivity of the mineral soil	$k_{sat,min,i} [S_{0,i}] = 0.0070556 \times 10^{-0.88+0.0153(\% \text{sand})_i} \times 10^{-0.88+0.0153(\% \text{sand})_i} \times 2(1 - (\% \text{gravel})_i) \times (2 + (\% \text{gravel})_i)$	$k_{sat,min,i} [S_{0,i}] = 0.0070556 \times 10^{-0.88+0.0153(\% \text{sand})_i} \times 10^{-0.88+0.0153(\% \text{sand})_i} \times 2(1 - (\% \text{gravel})_i) \times (2 + (\% \text{gravel})_i)$
The solid thermal conductivity of the mineral soil	$\lambda_{s,min,i} = \frac{8.80(\% \text{sand})_i + 2.92(\% \text{clay})_i}{(\% \text{sand})_i + (\% \text{clay})_i}$	$\lambda_s = \lambda_{s,min,i}^{1/4} \lambda_{s,max,i}^{3/4}$
The thermal conductivity of the dry mineral soil	$\lambda_{dry,min,i} = \frac{0.135\rho_{d,i} + 64.7}{2700 - 0.947\rho_{d,i}}$	$\lambda_{dry,min,i} = 0.917 \times 10^{-1.29\theta_{sat,min,i}}$
The bulk density	$\rho_{d,i} = 2700(1 - \theta_{sat,i})$	$\rho_{d,i} = 2700(1 - (\% \text{gravel})_i)(1 - \theta_{sat,min,i}) + (\% \text{gravel})_i \times \rho_g$
The solid heat capacity of the mineral soil	$c_{s,min,i} = \frac{2.128(\% \text{sand})_i + 2.385(\% \text{clay})_i}{(\% \text{sand})_i + (\% \text{clay})_i} \times 10^3$	$c_{s,min,i} = \frac{2.128(\% \text{sand})_i + 2.385(\% \text{clay})_i + 2.28(\% \text{gravel})_i}{(\% \text{sand})_i + (\% \text{clay})_i + (\% \text{gravel})_i} \times 10^3$
The Kersten number	$K_{e,i} = \begin{cases} \log(S_{r,i}) + 1 \geq 0, & T_i \geq T_f \\ S_{r,i}, & T_i < T_f \end{cases}$	$K_{e,i} = \begin{cases} \frac{1.7S_{r,i}}{1 + 0.75S_{r,i}} & T_i \geq T_f \\ \frac{4.6S_{r,i}}{1 + 3.65S_{r,i}} & T_i < T_f \end{cases}$

$\% \text{sand}$ relative percentage of particle size content
 SOC soil organic carbon
 f volumetric proportion of rock-forming mineral
 S_r degree of saturation

- The improvement of the soil hydraulic parameters is based on the relationship between the soil texture and the soil hydraulic parameters developed by Cosby. After a number of numerical experiments, we confirm the slope of gravel.
- The soil thermal conductivity of the solid particle is developed by the simplified version from Côté, which considers the quartz only. The Kersten number and the thermal conductivity of dry soils also from the empirical relationship proposed by Côté.

Table 1. The detail about the gravel schemes and the original schemes.

Assessment

- The shallow soil temperature simulated by the gravel schemes increases by 0.5°C on average compare with that of the original schemes. The deep soil temperature simulated by gravel schemes also increases especially in the western TP where the difference can be up to 2°C.
- High MAE region both the two schemes are centered in the western TP. However, the area of the high MAE from the gravel schemes is much small than that of the original schemes.
- The gravel schemes restrict the excessively shallow soil SM simulated by the original schemes and increase the deep soil SM in western TP.
- The gravel schemes ameliorate significantly the simulation effect of the soil moisture compare with the original schemes on the entire TP.

Fig 4. The spatial distribution of the mean absolute error for the soil temperature and moisture. The four figures above are soil temperature, and the four figures below are soil moisture. Left column: gravel schemes. Right column: original schemes.

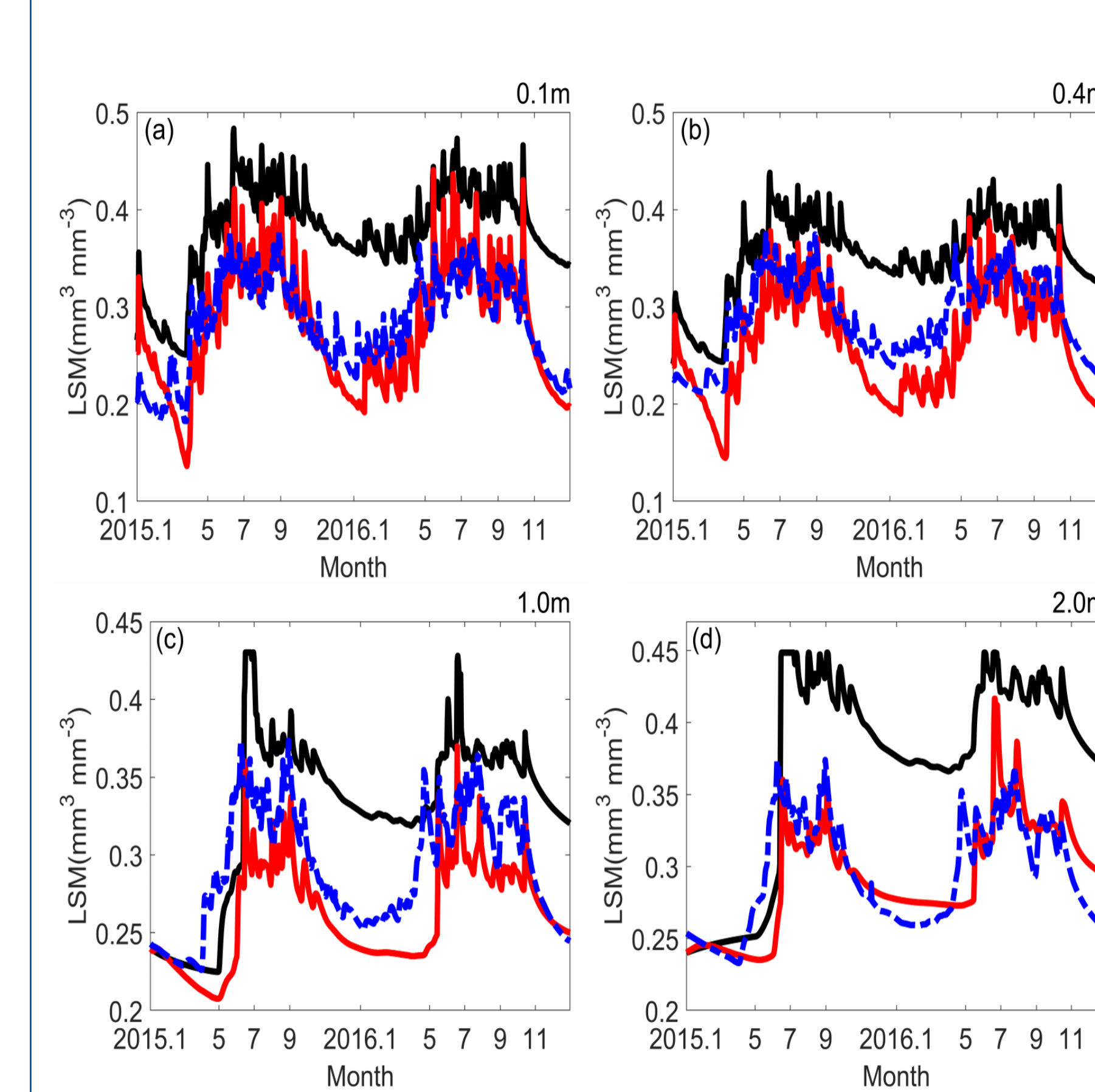


Fig 5. Time series of the SM simulated by the gravel schemes (red line) and the original schemes (black line) in the eastern TP and corresponding features in reference data (blue dashed line).

- The performance in simulating the SM by the gravel schemes in the whole soil layers is significantly improved, the temporal variation is more similar to that of the reference data and the excessive SM from the original schemes has been restricted.
- At the soil depths of 0.1 m and 0.4 m, the MAEs between the simulations by the gravel schemes and the reference data are 0.026 and 0.032, which are lower than the values of 0.101 and 0.070 from the original schemes, respectively.
- the correlation coefficients between the simulations by the gravel schemes and the reference data increase from 0.82 and 0.84 to 0.85 and 0.87 compared with those by the original schemes at the soil depths of 0.1 m and 0.4 m, respectively.
- At the soil depths of 1.0 m and 2.0 m, the MAEs are reduced from 0.052 and 0.102 to 0.028 and 0.018, respectively.

Vertical soil moisture migration

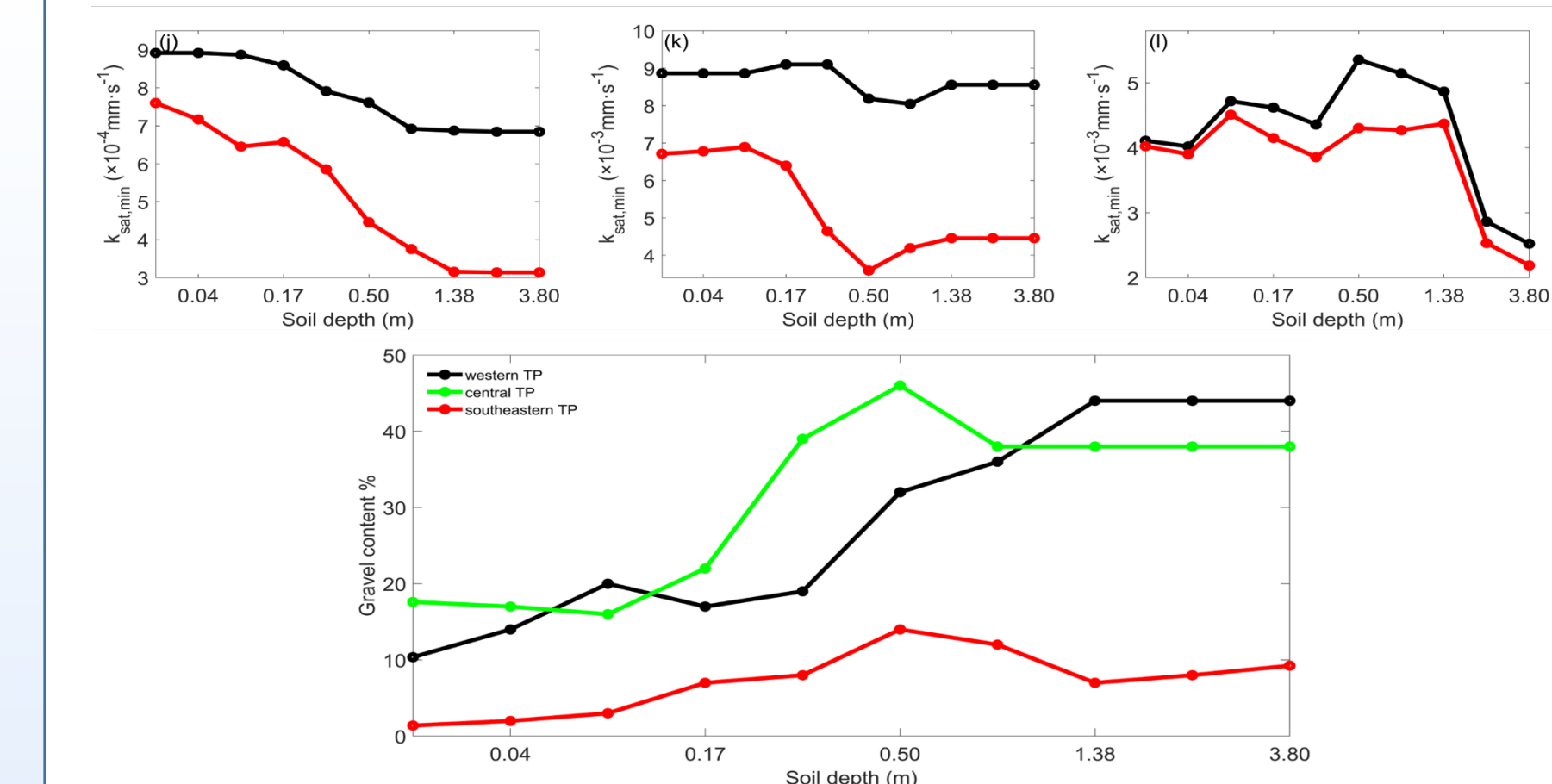


Fig 6. The three pictures above are the vertical feature for the saturated hydraulic conductivity of the mineral soil in the western TP (j), central TP (k), southeastern TP (l).

- The vertical feature for the saturated hydraulic conductivity of the mineral soil corresponds to that of the gravel content. The feature is different in the various regions on TP.
- The gravel decreases the saturated hydraulic conductivity of the mineral soil, and the decreasing magnitude is related to the gravel content.

Conclusion

- The performance of the gravel schemes in simulating the soil hydrothermal parameters is improved compared with the original schemes.
- The error for the soil temperature in the western TP is still significant. Besides the southeastern TP, the performance in simulating the temporal variation of the SM below the middle soil layers still needs to be improved.
- The increase of gravel content exerts a negative effect on saturated hydraulic conductivity.