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Interactive Comment

Interactive comment on "A scheme for calculating soil moisture content by using routine weather data" *by* K. Z. Shang et al.

K. Z. Shang et al.

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Dear Editor:

This is the point to point replies to the reviewers' comments on our manuscript.

Kezheng Shang

Reply to Referee 1

We would like to thank the anonymous reviewer for the detailed review of our manuscript which gives us the opportunity to clarify some points. In the following we quoted each review question in the square brackets and added our response after each paragraph.

[1. Intuitively, ground vegetation cover plays an important role in modulating soil mois-

EGU

ture and also the formation of sand storm. In the derived equation, I didn't see the explicit role of vegetation. Can the authors explain this?]

Indeed, ground vegetation cover plays an important role in the preservation of soil moisture and the formation of sand storm. Generally, daily weather elements and soil moisture may change greatly, but ground vegetation cover changes very little in half a month (or even in a month). Therefore, vegetation cover can be seen as a constant in the short term. In equation (23) (S= A+ BX), A is the background soil moisture content when there is no rain for a long time, and B is the response factor of soil moisture to precipitation. Because ground vegetation cover is helpful to soil moisture preservation, so A is higher when ground vegetation cover is more, and A is lower when ground vegetation cover is less. According to the regression analysis for the 79 stations, A is positively correlated with precipitation and cloud cover, but negatively correlated with annual average temperature. So, the distribution of A accords well with the distribution of ground vegetation cover, cloud cover, and annual average temperature in northern China. And B is negatively correlated with longitude, which means that the response of soil moisture to precipitation becomes weaker with the increase of ground vegetation cover. Therefore, the influence of ground vegetation cover on soil moisture is implicit in equation (23).

[2. The soil moisture scheme is established based upon 79 stations. But the validation is only conducted at 7 stations which seems not very convincing. On the other hand, from the operational point, for sand-storm forecast, I assume spring/early summer soil moisture is very important. Thus, a comparison between calculated soil moisture time series to those of observations are highly desirable.]

We agree to the opinion of the reviewer . But the problem is that the soil moisture data from 01/01/2003 to the present at the 79 stations have not yet been proofed by the National Meteorological Center of China and thus can't be used. The data for the 7 stations in the east of Gansu in China from 2003 to 2005, on the other hand, have been proofed by the Gansu Meteorological Information Center of China and thus

ACPD
7, S4653–S4661, 2007

Interactive Comment

EGU

can be used. Specially, the 7 stations are not among the 79 ones mentioned above. In addition, the 7 stations are located in the geographical center of China and thus representative. Therefore, the validation based on the data from the 7 stations is the best we can do at the moment. Besides, back validation using historical data from the 79 stations shows that the average error is from 2

We have done a comparison between calculated soil moisture time series to those of observations. The variation of calculated soil moisture content from 2003 to 20005, for 7 agro-meteorological stations in the east of Gansu Province in China, accords well with the variation of observed soil moisture content.

[3: The calculation scheme is for irregular observational points, the authors should explain how the results then were transfered to the regular model grids, e.g., via interpolation etc. Then how such transformation will affect the results.]

[5 Observations are not always handy, while numerical model outputs are easy to get. What's the prospect to use model outputs or hybrid forcing (a combination of model outputs and obs.) to derive soil moisture in the scheme instead of using observations only. This may be easier to implement as there is no need to worry about missing data or lacking of observations. Also, in a changing climate, the relationship can change too. Using model outputs may help to resolve this problem. Can the authors comment on this aspect?]

Reply to question 3 and question 565306;

Though the calculation scheme is established by using data from irregular observational points, it reveals the relationship between ground soil moisture and meteorological elements. So, we think that the scheme can also be used to calculate the ground soil moisture at regular points. There are two methods to calculate soil moisture at regular grid points. One is to calculate the soil moisture at irregular observational points first and then get the soil moisture at regular grid points by using interpolation. Another is to interpolate the meteorological elements at irregular observational points into the

ACPD

7, S4653–S4661, 2007

regular grid first and then calculate the soil moisture at regular grid points. However, both methods can bring evident errors in areas where meteorological stations are few or altitude difference is great. As the reviewer has pointed out, it will be a good idea to combine model outputs with observational data to obtain meteorological elements first and then soil moisture at regular grid points.

[4: Almost all current numeric models have soil hydrology scheme that will calculate spatial-temporal-varying soil moisture. In addition, there are many land surface schemes too. Then, it would be very interesting to see, compared to some of them (e.g., reanalysis soil moisture or offline model simulated soil moisture), how much improvements this method can produce in estimating soil moisture and forecasting sandstorm in the retrospective sense. A reason for this is that such products (e.g., reanalysis soil moisture) is routinely updated through the assimilation system.]

We have compared soil moisture calculated by this scheme with that from NOAA CPC. In NOAA climate prediction center (CPC), global soil moisture is estimated by a one-layer (1.6m in thickness) hydrological model. The unit for soil moisture is millimeter (mm). Global monthly soil moisture can be downloaded from NOAA CPC. Dividing this monthly soil moisture by 1600, we get soil moisture in percentage. The distribution of calculated soil moisture in China from Mar. 2006 to May 2006 is very similar to that from NOAA CPC. The isoline of soil moisture content at 5

[6: The authors should check the reference in the paper and review the introduction more carefully. E.g, P3, "In most numerical models, soil moisture content in China is treated as a constant ...". This shouldn't be the case. Almost all GCMs, though differing in the treatment of land surface hydrology, treat soil moisture as a time-dependent variable. This can be easily seen by looking at the recent IPCC AR4 models. Also P3, "Entin et al., 1999" is not about calculation soil moisture content. Also P3, "But this type needs real-time soil moisture content data of multiple layers as initial values and thus can not be used widely". This is definitely not true. Although true soil moisture initial conditions are hard to obtain, there are many spin-up methods available to reduce if

ACPD

7, S4653–S4661, 2007

Interactive Comment

not complete remove the effects of unrealistic initial conditions. P4 Line 2 "This type is good for drought monitoring and the climatic evaluation of soil moisture, but not so good for daily soil moisture content retrieval". The authors should explain why as not all readers have the necessary background.]

"In most numerical models, soil moisture content in China is treated as a constant ..." is revised as “In most sand-dust numerical models developed by Chinese, soil moisture content in China is treated as a constant, Ě.”.

delete "Entin et al., 1999" from the text and the references.

"But this type needs real-time soil moisture content data of multiple layers as initial values and thus can not be used widely". Revised as “Because real-time soil moisture content data are hard to get, so the initial values of soil moisture content need to be deduced by using other methods, such as remote sensing. ”

There are many methods for soil moisture monitoring by using remote sensing. They can be divided into two kinds: optical remote sensing and microwave remote sensing. Optical remote sensing, the most widely used kind so far, includes methods such as improved thermal inertia, crop water shortage index (CWSI), and vegetation index. The thermal inertia method is good for bare soil or land surface covered with sparse vegetation, but it suffers from the interference of cloudy weather. So, in practice, remote sensing data within a period of 10 days are usually used to monitor soil moisture. The CWSI and vegetation index methods are good for land surface covered with dense vegetation. But they mainly represent the soil moisture in the root zone. The daily variation of soil moisture is weaker in the root zone than at the surface. So, at present, soil moisture monitoring by remote sensing is manly used in drought monitoring and the climatic evaluation of soil moisture.

[7: The application part, when comparing the forecasting result, the authors should explain in more detail of Figure 4 to demonstrate that soil moisture from their scheme help to improve the forecasting.]

ACPD

7, S4653–S4661, 2007

There are some mistakes in Fig. 3, so Fig. 3 and Fig. 4 will be replaced by new ones. We will explain in more detail in the new figures.

[8: With respect to conclusions part, Conclusion 1 seems ungrounded or at least is not the results of this paper. This has to be done by. e.g., looking at auto-correlation between sm and P. Additional contents are needed to support (3) and (4) [refer 1-5,7].

The delay-cross-correlation coefficient between precipitation and soil moisture declines with the lag time. When lag time is more than 7 days, the average delay-cross-correlation coefficients between precipitation and soil moisture for 79 agro-meteorological stations in China becomes so low that it can't pass the significance test at the level of 945; =0.1 (average samples=448, so, rc=0.078). But this don't mean the influence of precipitation on soil moisture does not go beyond 7 days. When we use the compound factor X (see Eq. (19) and (20)) to consider the influence of precipitation on soil moisture, we find the cumulated influence reaches it maximum value at 16 days. Thus Conclusion 1 is obtained.

Reply to Referee 2

We would like to thank the anonymous reviewer for the detailed review of our manuscript which gives us the opportunity to clarify some points. In the following we quoted each review question in the square brackets and added our response after each paragraph.

[1 This special issue is for the CUACE/Dust system. What is the dust event operational forecasting system (DOFS) of the National Meteorological Center in China? It would be nice to show the application of this scheme in the CUACE/Dust system.]

We have deleted the part related to DOFS and done the application of this scheme in the CUACE/Dust system. From 8 to 11/04/2006, a strong dust storm event occurred in North China and Mongolia. We have simulated this dust storm event by using the CUACE/Dust system with two soil moisture values as input conditions. At 10/04/2006,

ACPD

7, S4653–S4661, 2007

Interactive Comment

06:00 (UTC), sand dust occurred in two areas. The first area was in South Mongolia and North China. For this area, the dust flux distribution simulated based on the soil moisture calculated using by our scheme as input conditions is closer to the actual sand-dust distribution than that simulated based on the soil moisture given by the CUACE/Dust system as input conditions. The second area was in the Taklimakan. For this area, the simulated results by using both soil moisture values are all close to the actual sand-dust distribution. The above results show that the forecasting accuracy of the CUACE/Dust system for East China can be improved by using our scheme. Because the accuracy of sand-dust forecasting in East China is more important than that in West China, so our scheme can be used to improve the CUACE/Dust system.

[2 Figure 3 showed the soil moisture calculated from the proposed scheme. Please mark the unit of soil moisture in the figure. The scale of the soil moisture used in the figure needs to be changed. A scale between 0.1 and 5 was not appropriate. Moisture in the range of 0.1 to 5

[3. Soil moisture observations from the agro-meteorological stations have some bias compared to the natural soil moisture in the desert areas due to the irrigation practice. This may reflect the problem in Figure 3. Comparison with other data, such remote sensing data, would help to validate the scheme for using the dust storm forecasts. It is suggested that results from this scheme be compared with other type of soil moisture data.]

Reply to question 2 and question 3

As the reviewer has pointed out, soil moisture date from some agro-meteorological stations in Xinjiang and Gansu are indeed influenced by irrigation. As a result, some observed soil moisture values are too high and thus not representative of large-scale areas. Eliminating these abnormal data, we can revise Eq. (23), (25), (27) and (29) as follows:

A=1.21-0.758x4+0.018x5+1.81x6 R=0.6742

ACPD

7, S4653–S4661, 2007

Interactive Comment

B=6.56-0.040x2 R=0.5332 (23)

A=1.50-0.732x4+0.018x5+1.77x6 R=0.6786

B=4.45-0.029x2 R=0.6762 (25)

A=1.02-0.736x4+0.018x5+1.84x6 R=0.6768

B=9.81-0.061x2 R=0.5902 (27)

A=0.87-0.738x4+0.018x5+1.96x6 R=0.6876

B=3.68-0.023x2 R=0.6189 (29)

According to Eq. (22) (S=A+BX), the value of A in Eq. (23), (25), (27) and (29) should be the lowest soil moisture content. But, it's not the case in reality. The value of A is higher than the lowest soil moisture content (LSM) for the 79 agro-meteorological stations. In order to fit the situation in which there is no rain for a long time, Eq. (22) needs to be modified.

Let: RA= A/ LSM

Through statistical analysis, we find RA is correlated with altitude(x3), so we get:

RA=3.0-0.0005x3 (30)

Therefore, Eq. (22) can be modified as follows:

S=A/ RA + RAŢBX when X<A/B/ RA or RA<=1

S=A+BX when X>= A/B/ RA and RA>1 (31)

The lowest soil moisture content in China calculated by using Eq. (23) (30) and (31) is less than 5

Test by using historical data from 1981 to 2002 for the 79 agro-meteorological stations shows that the average error is between 2

ACPD

7, S4653–S4661, 2007

We have done the comparison of soil moisture calculated by using this scheme with soil moisture from NOAA CPC.

[4 Figure 4 showed the comparison of dust storm forecasted from two soil moisture inputs. Improvements are seen from the figure. However, large differences between these two forecasts over the Pacific and part of India were shown up. This seems rather strange. An explanation is needed.]

There are some mistakes in Fig. 4. It will be replaced by new validation results.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 7451, 2007.