Response to Referee #2:

This paper discusses the retrieval of surface soil moisture from brightness temperatures measured with SSM/I sensor. After a validation of moisture products, using ground truth measurements and GLDAS-Noah soil moisture simulations, an analysis of normalized soil moisture anomalies and their trends are proposed. Using 19.4 GHz, soil moisture products are proposed for a very limited penetration depth (about some millimeters). Because of different effects (vegetation, atmosphere, roughness), and the high sensitivity of these measurements to atmospheric conditions, it seems very complicated to consider SSM/I retrieval for analysis of annual or monthly trends.

Authors' response:
We would like to thank the reviewer for carefully reading our manuscript. Unfortunately, the reviewer appears to be somewhat skeptical regarding the soil moisture retrieval from SSM/I brightness temperature. As the issues highlighted above appear also in the comments below, we hope to convince the referee with our point-by-point response to the individual items below.

Different points have to be clarified.
1) The discussion of soil moisture anomalies using a 19.6GHz sensor seems not evident. In fact, high variation of soil moisture in the first millimeters is linked to important effect of meteorological conditions and evaporation. It is not clear how to retrieve annual or monthly trends.

Authors' response:
The trends are obtained by averaging the daily soil moisture retrievals to monthly soil moisture values and the monthly values to annual values. Then, based upon time averaged values (either monthly or annual) soil moisture the anomalies are computed, which are used to extract the trend by fitting a linear to the anomaly-time pairs. The slope of the linear function is taken as the trend. This is described in section 5.1 on P6643L22-P6644L18, but perhaps it is not clearly formulated as Referee #3 also had some questions on this part of the manuscript. The monthly trends are, thus, the trends computed from the averaged soil moisture for a specific month (e.g. May, June, July, August, September, and October) over the years 1987-2008. The annual or 'warm season' trend are trend computed from the 'warm season' mean soil moisture over the period 1987-2008. We hope that this clarifies the text.

2) The authors consider that penetration depth for 19.4 GHz is about 1.55 Cm. If we consider theoretical equations, penetration depth is only about some millimeters. In C band (5.3 GHz for example), we consider a depth of about 2 cm!

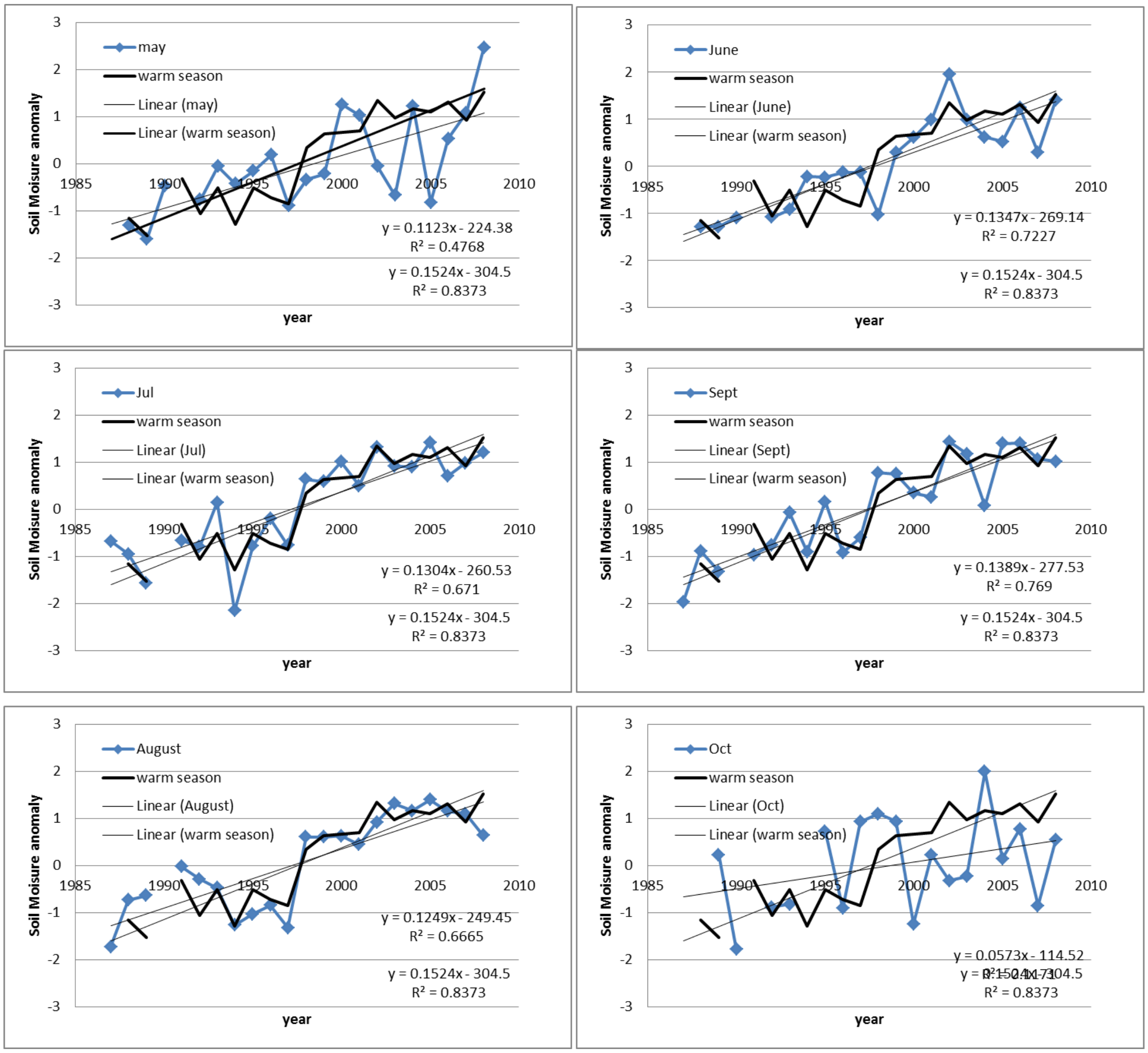
Authors' response:
The reviewer is correct the theoretical sensing depth of 19.4 GHz is shallow and varies in fact also with the moisture content in the soil profile. It is, however, very difficult to make reliable measurements of such shallow soil layer. The common practice is, therefore, to validate retrievals against measurements of the 0-5 cm layer. This approach has previously been adopted for SSM/I soil moisture retrievals by, for instance, Wen et al. (JHM 2005) and Jackson et al. (JHM 2001). In this study, we show that the matchup of SSM/I retrieval with measurements acquired by probes installed at 2.5 cm depth produces error statistics that are in line with the state of the art.

3) Authors consider Dobson et al. 1985 model for retrieving of soil moisture from dielectric constant, or proposed model is validated only between 1.4 GHZ and 18GHZ?

Authors' response:
Indeed, the Dobson et al. (1985) model is developed using measurements collected in the 1.4-18 GHz frequency. In the 4-18 GHz range, the Dobson's model relies on measurements made with an increment of 2 GHz. As such, Dobson et al. (1985) considered the measurements not to vary a lot over the +/- 1 GHz range. Similarly, we assume in this study that Dobson's dielectric mixing model is valid up to 19.4 GHz. This assumption has previously been adopted by others, for instance, Jackson et al. (2001). The text will be modified to highlight this assumption.

4) How authors explain higher trends for annual anomalies than for monthly anomalies in figure 10.

Authors’ response:
Based upon the referee’s comment, the monthly soil moisture values have been extracted for a pixel in the area with the largest trend. From these values, the monthly anomalies and warm season (annual) anomalies have been computed and the trends are determined by fitting a linear equation through the anomaly-year pairs. The results are presented in the figure below whereby for each of the six months (May to October) the monthly as well as the warm season anomalies are plotted against the year. In addition the linear fit is plotted and the equation is shown in the lower right corner.



The six plots show that the slopes of all the equations fitted through the monthly anomalies are smaller than the slope of the warm season anomaly trend. An analysis of the individual plots shows that the monthly anomalies are much more susceptible for fluctuations, which is the explanation for the smaller monthly slopes. The larger monthly fluctuation has two main reasons: 1) the monthly interannual variability is larger than the warm season interannual variability and 2) the warm season anomalies are based upon a larger number of retrievals than the monthly anomalies, which suppresses the variability with the warm season signal as compared to the monthly signal.

This impacts, of course, the significance of the monthly trends. It is, therefore, observed in Figure 9 that the number of pixels with significant trends is much smaller as compared to the annual trend in Figure 8.

5) What depth is considered for ground measurements, 2.5cm, to validate satellite products?

Authors' response:
The measurements by the probes inserted at a depth of 2.5 cm for the three grassland sites and at 7.5 cm for the wetland site are used for validation the daily retrievals, which is assumed to represent the moisture content of the 0-5cm soil layer.

6) Authors don't consider vegetation effect in the proposed inversion algorithm, or for 19.4 GHz, sensitivity to vegetation cover (even dispersed) could be very important.

Authors' response:
The algorithm we have used for soil moisture retrieval makes use of the τ-ω model whereby the dieletric constant (determined by soil moisture) and τ (vegetation optical depth) are retrieved simultaneously. Thus, the algorithm does account for vegetation effects.

7) Figure 5 shows comparison between ground measurements and satellite retrieval. What is the limitation of satellite products based on high frequency sensor? Even in C band, we observe some difficulties in medium soil moisture because of heterogeneity of soil moisture profile (Amri et al., IEEE TGARS, 2012).

Authors' response:
The limitations and justification for using high-frequency microwave observations for soil moisture retrieval are described in the introduction P6631L27-P6632L9.

Further, the study by Amri et al. (2012) cannot be compared to this one because the authors have used scatterometer data whereas the SSM/I is a radiometer, because microwave emission and scattering processes can differ quite a lot in terms of sensitivity to surface heterogeneity, particularly to surface roughness. Moreover, the study areas have different soils and hydro-meteorological characteristics. It can be expected that under varying soil moisture conditions the penetration depth changes significantly for sandy Tunisian soils.

8) Authors consider inversion at low spatial resolution (pixel: 25km). What about errors due to heterogeneities and particularly presence of lakes? What about errors due to spatial scale for validation with ground measurements?

Authors' response:
We did not quantify the uncertainties associated with the presence of lakes. This is indeed a potential error source for soil moisture retrievals, but beyond the scope of this study. For the trend analysis, we make use of standardized anomalies and assume that the change in lake surface area does not alter the impact on the microwave emission significantly.

The various curves in Fig. 5 provide an indication of the soil moisture variability that can be measured within an SSM/I pixel. Plot shows that the measured variability is considerable. However, this does not add uncertainty to the retrievals; it adds uncertainty to the validation process of the retrievals. The validation results are not perfect but quite reasonable (RMSE = 0.046 m^3 m^{-3}) for high frequency microwave observations.

9) Authors consider trends function of elevation (with a bin of 50m). How they consider this analysis with low resolution pixels, combining probably different elevation levels?

Authors' response:
We first aggregate the GTOPO30 DEM to the SSM/I spatial resolution by averaging all the pixels within an SSM/I pixel. The pixel averaged GTOPO30 elevation is matched with the SSM/I observed trend.

10) It will be important to illustrate a comparison between GLDAS simulation and satellite measurements, showing multi-annual variations like for figure 5.

Authors' response:

We agree with the referee that including the GLDAS simulated soil moisture to figure 5 will be informative and this will be done in the revised manuscript. However, long term soil moisture trends of GLDAS-Noah at 0.25^o resolution are not so useful because for various episodes different sets of atmospheric forcings have been used (see 2004ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/GLDAS_V1/README.GLDAS.pdf p5).