Geosci. Instrum. Method. Data Syst. Discuss., 5, C41–C46, 2015
www.geosci-instrum-method-data-syst-discuss.net/5/C41/2015/

Geoscientific Instrumentation Methods and Data Systems
Discussions

Interactive comment on "Global trend analysis of the MODIS drought severity index" *by* P. I. Orvos et al.

P. I. Orvos et al.

imre.janosi@ttk.elte.hu

Received and published: 21 June 2015

Reply to the comments of Referee 2

We thank the careful reading of the manuscript and the supporting general comments. Please find here our responses to the critical remarks. For the sake of clarity, we quote the related sentences of the Referee in italic.

"A. The observed trends reveal climate variability of the order of 10 years rather than long-term global climate change, as also is mentioned in the paper and discussed in Chapter 3. The possibility that the observed DSI trends are related to decadal modes (as stated in the end of Ch. 3) requires further discussion and support from other

investigations. Please expand this section."

We expanded this section by citing recent key studies, however we want to be careful. The main conclusion of the quoted works is that the question is more or less open, and our tools are very limited apart from mentioning the main problem.

"The relatively short period of 12 years is not enough to connect the results with global climate change. We think that the observed significant DSI trends over extended geographic areas are related to a decadal mode of the natural climate variability. Apart from time-span limitations, recent studies on drought trends (Sheffield et al., 2012; Dai, 2011, 2013) lead to somewhat controversial conclusions, as noticed by Trenberth et al. (2014). One major issue in determining reliable long-term trends in drought due to climate change is to separate the effects of natural variability, especially El NinËIJo/Southern Oscillation (ENSO) (Trenberth et al., 2014). During El NiËIJno events, the main rainfall systems in the tropics move eastward over the tropical Pacific ocean leaving weakened monsoons behind (Panda and Kumar, 2014; Barreiro et al., 2014). In the La NiËIJna phase, dry areas are more common in places where it is wet during El NiËIJno events. Indeed, as Miralles et al. (2014) pointed out in a recent study, ENSO dominated the multidecadal variability of terrestrial evaporation at the global scale. Their main conclusion is that the recent decadal decline in global average continental evaporation is not the consequence of a persistent reorganisation of the terrestrial water cycle, but rather it is an indication of transitions to El NiËIJno conditions (Miralles et al., 2014)."

"B. The methodology description in Ch 2 (data methods) is far too thin. Please explain more in detail your methods. This part is in the core of this paper when submitted to GI, and hence you should draw a more clear picture of the methodological system (explain) linking the data with your conclusions."

Thanks, we agree. The Section "Data and Methods" is revised substantially, as follows:

"In order to better exploit the strengths of continuous satellite observations, **?** have recently developed a remotely sensed global drought severity index (DSI), and compiled an open access data base spanning 12 years between 2000 and 2011 at a temporal resolution of 8 days. The highest spatial resolution is around 5 km ($0.05° \times 0.05°$) with an almost global coverage. The definition of DSI incorporates the normalised difference vegetation index (MOD13 NDVI product), together with the evapotranspiraton and potential evapotranspiraton ratio data (MOD16 ET/PET product).

The NDVI vegetation index measures the fraction of photosynthetically active radiation absorbed by plant canopies, basically the amount of vegetation present on the ground (**???**). By design, the dimensionless NDVI is a transformation of the near-infrared/red spectral reflectance ratio, and it varies between -1.0 and +1.0. Relatively large negative values occur when red reflectance exceeds near infrared one corresponding to water surfaces, values around zero are characteristic for barren areas, while positive values span from grasslands trough midlatitude forests up to tropical jungles.

Terrestrial evapotranspiration (ET) is the sum of evaporation and plant transpiration from land surface to the atmosphere. The computation algorithm of MOD16 ET is based on the theory of Penman-Monteith energy balance by using remote sensing inputs of the leaf area index, land cover, albedo, and enhanced vegetation index, furthermore meteorological parameter values of radiation, air temperature, pressure, and humidity (**??**). Over a sufficiently long time period, ET is less than or equal to precipitation for most vegetated geographic locations, apart from sites where irrigation or subsurface water supply may shift the balance. Tropical forests have the highest ET values, dry areas and areas with short growing seasons exhibit low ET, while values for temperate and boreal forests lie between the two extremes. Potential evapotranspiration (PET) is the amount of water that would be evaporated and transpired in case of hypothetically infinite water availability, incorporating the energy available for evaporation and the ability of the lower atmosphere to transport evaporated moisture away from the land surface. ET and PET are expressed in terms of depth of water (mm) for a given time period (day, week, month, etc.), thus the ratio ET/PET has a value of 1.0

where evapotranspiration fully satisfies potential conditions, and declines toward zero where the surface dries.

A given DSI value is obtained by standardisation of the sum of previously and separately standardised NDVI index and ET/PET ratio (**?**):

$$Z = \frac{NDVI - \langle NDVI \rangle}{\sigma_{NDVI}} + \frac{ET/PET - \langle ET/PET \rangle}{\sigma_{ET/PET}} \quad , \tag{1}$$

$$DSI = \frac{Z - \langle Z \rangle}{\sigma_Z} \quad . \tag{2}$$

Temporal mean values $\langle * \rangle$ and standard deviations σ_* are determined over the available time period for each gridpoint separately. It is an important detail that DSI is derived using ET/PET without NDVI during the classified dormant season, because of greater noise in the non-growing season NDVI signal (**?**). Permanently non-vegetated locations such as deserts, high mountains, extended lakes, or large cities cannot provide useful input for DSI data, therefore such gridpoints are filtered out by a quality assessment procedure (**?**). Note that zero DSI values are not equivalent with missing data, standardisation procedure defined by Eqs. (1) and (2) shifts local mean values to this level by definition. There are two essential aspects to be also emphasise at this point: (i) Standardisation enhances small fluctuations or seasonal changes with the normalisation by the local standard deviations σ_*, and (ii) standardisation does not remove any trend existing in the time series, furthermore it does not change the statistical significance of trends in any sense.

DSI records at 4914440 geographic locations are evaluated in order to identify linear trends. Each individual record consists of 552 points covering 12 years from 01/01/2000 to 12/31/2011. The basic time-step is 8 days, apart from the necessary cuts at the end of each year. Example time series and linear trends are shown in Fig. **??** for three nearby locations (at the same latitude) in Argentina, where significant negative trends are identified (see below). Note that the time series exhibit apparently weak seasonal and annual variations, in spite of the fact that the climate of province of Córdoba is humid subtropical with four marked seasons. This is mostly because the ET/PET term in DSI [see Eq. (1)] has a feeble seasonal variability in many places (**?**), moreover NDVI is incorporated only during the classified snow-free growing seasons as noticed before.

Statistical significance of slopes of linear fits is verified by the standard permutation test (**?**). Since most of the DSI signals exhibit marked persistence on time scales of weeks or even months (see Fig. **??**), the basic unit of data shuffling was one whole calendar year. We cut a given record into 12 pieces, and built a test set from randomly shuffled and glued years. The mean slope and standard deviation σ were determined, and we accepted a fitted slope of a measured record to be significant when its distance from zero was larger than 2σ of its own test set. Fig. **??** illustrates that a test set size of 100 samples provides essentially the same statistics as 100000 random samples, however for the sake of minimising errors we fixed the test set size as 1000 samples. Obviously the larger the sample size the closer the histogram of obtained slopes to a pure Gaussian (not shown here), however the mean and variance do not show detectable sensitivity to the size of the test sets (Fig. **??**)."

"C. The Conclusions section is not ready. The authors should - First tell the objective - summarize what was performed and how - Results in another format than a list of bullets - Recommendations for future work."

Please find here the revised version:

"The objective of the present work was to perform a global linear trend analysis of the remotely sensed drought severity index (DSI) compiled by **?**. The methodology was very similar to other studies on vegetation indices (NDVI or SDVI) **???** with the main difference that our significance test is based on the direct permutation method. Detailed comparisons mostly with the results of **?** indicate that DSI performs somewhat better in detecting significant negative trends. This can be a consequence of the defini-

tion of DSI, where ET/PET ratio provides a continuous contribution to the signal, while NDVI participates only in the growing season. On the other hand, this definition complicates the interpretation of observed trends, because the two terms are not functionally related, therefore the separation of contributions is not trivial. We have illustrated the power of high resolution mapping by zooming to restricted regions and providing reasonable explanations why local trends can have opposite signs to the surrounding extended area.

Work is in progress in three directions in order to find a better explanation of the observed trends. Firstly, it is a plausible goal to repeat the analysis separately for the two terms (standardised NDVI and ET/PET ratio) to identify precisely the role of these factors. Secondly, it is reasonable to compare DSI with the many existing drought indices. This is a demanding task, mostly because the validation of the various time series certainly requires direct comparisons with field observations. Thirdly, decadal trends over extended geographic areas call an explanation related to global climate change, especially when the subject has such a trivial societal impact as for a drought severity index. This is a highly nontrivial problem too, because the separation of natural climate variability from unambiguous climate shifts is hindered by the length and reliability of available data (**?**). Nevertheless cross-correlation analyses with relevant atmospheric variables are necessary to begin the procedure. Candidate indices are El Niño/Southern Oscillation, Northern Annular Mode/North Atlantic Oscillation, Southern Annular Mode, sea surface temperature (SST) anomalies, sea ice cover (SIC), Atlantic Multidecadal Variability, etc. "

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 19, 2015.