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Hydrology and Earth System Sciences Discussions

# *Interactive comment on* "Interannual variations of the terrestrial water storage in the Lower Ob' basin from a multisatellite approach" *by* F. Frappart et al.

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We really wish to thank the anonymous Referee 2 for his comments which helped us a lot for improving the quality of the manuscript. Nevertheless, we want to clarify some points concerning the overview of our work.

The paper presents data from different satellites for 1993-2004 which have been extracted from extisting, already in the literature discussed datasets for the lower Ob basin. The novel part is the use of such data in hydrological models in this specific environment, but limited to the years 2003-2004 (GRACE data available only for these years). This is however presented as a minor part only. Permafrost is a very important factor in the lower Ob basin. It is mentioned that one of the used models can deal with



this issue, but no further explanation is given.

The novel part of this paper is mainly the monitoring of the time variations of the water storage in the mainstream and the floodplains of the Lower Ob' Basin over 1993-2004, combining information from radar altimetry and satellite imagery, as stated several times in the abstract (the first nine lines), the introduction (page 6650, lines 22-23), and the conclusion (the whole first paragraph). The analysis of the surface water compartment also represents the major part of the results presented in this paper. Contrary to what it is stated above, we did not just present and compile existing satellite datasets, but did a huge work of processing satellite data. We built a network of altimetry-derived water levels in the Lower Ob' Basin. To make this clearer, we replace the previous sentence describing the altimetry data page 6652, lines 10-15 with "In this study, we built an altimetry-based hydrological network of 90 (old orbit: 1993-2002) and 92 (new orbit: 2002-2005) time series of water levels derived from T/P measurements over the Lower Ob' drainage basin (see Fig. 1 for their locations), following the methodology proposed by Frappart et al. (2006a), for the period 1993-2004". Then, we estimated the surface water volume variations combining the altimetry-derived water levels with the inundated surfaces from satellite imagery. The Referee as also to remind that the multisatellite inundation dataset is produced by three of the co-authors (see section 2.2 The multi-satellite inundation dataset), the GRACE snow product by two others (see section 2.4 GRACE-derived land water and snow mass solutions), and the rescaling factor for the GRACE data by two others (see section 4.3 Rescaling of the GRACE data). It is true that for the very first time, a study proposed to isolate the groundwater component from the Total Water Storage (TWS) estimated using GRACE measurements in a peri-Arctic river basin. Previous studies generally proposed to remove the water stored in the first meters of the soil to the TWS in environment where there is no snow and no or negligible surface waters. Here, we removed from the TWS the surface water and the snow storage anomalies. As mentioned in the paper, the limiting factor to expand this study to more years is not the availability of the GRACE data (when we submitted this paper GRACE-derived TWS was available from 2002 to 2009, and the snow estimates from

2002 to 2007), but the availability of the multisatellite inundation dataset (1993-2004) and the Topex/Poseidon data (1993-2005 with a decrease of the quality of the measurements the last year of operation of the radar altimetry mission). In this study, we never used remotely sensed observations into hydrological models. As mentioned in the abstract ("Water stored in aquifer is isolated from the total water storage measured by GRACE by removing the contributions of both the surface reservoir, derived from satellite imagery and radar altimetry, and the root zone reservoir simulated by hydrological models"), the introduction ("Then, a new method, based on the combination of multisatellite-derived hydrological products and outputs from global hydrology models, is proposed to derive the spatio-temporal variations of water volume anomalies in the aquifer and the permafrost of the Lower Ob' Basin. Water storage anomalies in the different hydrological reservoirs are removed from the TWS measured by GRACE to isolate the sum of the groundwater and permafrost anomaly storage over 2003-2004."), and explained in the section 3.3 Total soil and groundwater storages estimates.

Suggestions

1) Focus on the model part. Extent the description of the model, especially discuss the representation of permafrost (different types)

We simply removed an average of the water stored in the root zone from LaD and WGHM outputs (along with the surface water derived from multisatellite data and the snow from GRACE) to the Total Water Storage measured by GRACE. We totally agree that the presence of permafrost in the Lower Ob' Basin is likely to be an important source of error in the modelled TWS from WGHM and LaD, as WGHM does not simulate accurately the permafrost activity, and LaD does not take into account this hydrological reservoir. To tackle with this problem, we added the time variations (Figure 7a) and annual amplitude (Figure 8c) of the total soil storage only based on remotely sensed observations in the corrected version of manuscript. So, only the last results are obtained using hydrological models outputs, reminding the reader that the soil storage represents only a small part of the TWS. To help the reader to keep in mind that the



models are inaccurate at high latitude and do not describe permafrost well, we added: - in section 2.5 Water in the root zone from hydrological models: "Unfortunately, it contains no representation of the permafrost" at the end of the description of the LaD model outputs, "This model employs a minimization function including a permafrost/glacier-related factor for the recharge of the aquifer described in Döll and Fiedler (2008)" at the end of the description of the WGHM model outputs, "It is important to keep in mind that these two models are unable to reproduce the complex mechanisms that occurred in the permafrost, active-layer, and talik, as described, for instance, in MacKay (1995)" at the end of the section. - at the end of section 4.4 Water volume variations: "Nevertheless, this last result has to be considered with caution due to the lack of relevance of the hydrological models used in this study to permafrost, active-layer, and talik". - in the conclusion: "It is important to keep in mind that soil storage from the hydrological models are likely to be erroneous due the inaccurate (WGHM) or lack (LaD) of modelling the permafrost, active-layer, and talik". We also modified the manuscript to take into account the estimate of the satellite-derived TSS. We decompose equation 1 into equations 1 and 2, added figures 7a and 8c, and modified section 4.4 Water volume variations: "The time variations in Terrestrial Water Storage (TWS) are the sum of the contributions of the different reservoirs present in a drainage basin: Delta TWS = Delta SW + Delta SN + Delta TSS (1) with Delta TSS = Delta RZ + Delta GW + Delta P (2) where SW represents the total surface water storage including lakes, reservoirs, in-channel and floodplains water, SN is the snow storage, TSS is the total soil storage including RZ the water contained in the root zone of the soil (representing a depth of 1 or 2 m), GW the groundwater storage in the aquifers, and P the permafrost storage. These terms are generally expressed in volume (km3) or mm of equivalent-water height". "TSS exhibits a strong North-South gradient, with larger variations in the eastern part of the basin, and following the permafrost distribution from Brown et al. (1998): high amplitudes around 30-35 mm in the South (especially in the South East) of the basin where the permafrost is isolated or sporadic to less than 15 mm in the North-East close to the mouth where the permafrost is discontinuous (Fig. 8c)". "Nevertheless, this last result has to be considered with caution due to the lack of relevance of the hydrological models used in this study to permafrost, active-layer, and talik".

2) Explain why you limit your analyses to the lower Ob basin

We added the following sentence at the end of the section 2.1 The Lower Ob' Basin: "The Lower Ob' is distinct from the Middle and the Upper Ob' in terms of hydrological regime, permafrost conditions, and river management (i.e., dams and reservoirs)", to explain why we have chosen to focus our study on the Lower Ob' basin.

3) revise English language!!!, e.g. page 6649, line 1: was reveal with -> was revealed with page 6652, line 9: comsomomly ? page 6653, line 11: up to a degree 60 -> up to 60 degree page 6654, line 1: annual rivers discharges -> annual river discharges page 6655, line 2: 'and the' missing ........ page 6661-2 (Conclusions) : ... to better the relationships ...? ... precipitation Seasonal...?

We corrected the errors mentioned by Referee 2, except the one mentioned one page 6653, line 11. Degree 60 refers to the maximum development of the harmonic coefficients of the monthly GRACE geoids. "Comsomonly" was replaced by "commonly", page 6652, line 9. We added "understand" between "better" and "the relationships" and a point between "precipitation" and "Seasonal". The manuscript has been revised to improve the quality of English and eliminate the typographical errors remaining in the submitted paper.

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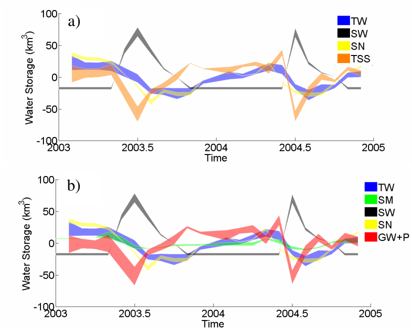


Figure 7. a) Monthly variations of TWS volume (blue), surface water volume from T/P radar altimetry and multisatellite inundation dataset (black), snow derived from GRACE measurements (yellow), TSS by difference between TWS and the other compartments (orange), Monthly variations of TWS volume (blue), surface water volume from T/P radar altimetry and multisatellite inundation dataset (black), soil moisture from hydrological model outputs (green), snow derived from GRACE measurements (yellow), sum of groundwater and permafrost by difference between TWS and the other compartments (red). Units: $km^3$.

**Fig. 1.**

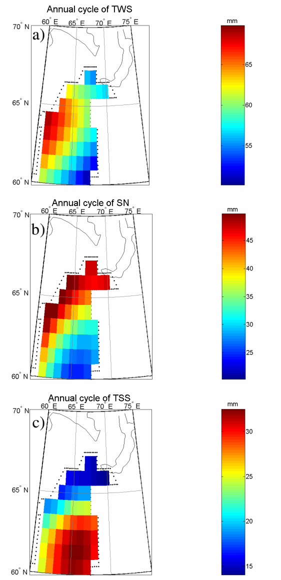


Figure 8. Amplitude of the annual cycle over 2003-2004: a) TWS from GRACE, b) Snow Water Equivalent (SWE) from GRACE, c) Total Soil Storage. Units: mm.

**Fig. 2.**