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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 1 for his very constructive comments which helped us a lot for improving the quality of the manuscript and to consider that our work as a base-line for future works concerning the hydrology of the Lower Ob'. We used one of his sentence to respond the second comment of Referee 2. We also added it to the manuscript.

Comments

1) the models have little to do with the terrain they are being employed to model

Once again, we really want to thank Referee 1 for all the interesting and pertinent pieces of information he gave us concerning permafrost. First of all, we want to precise that we did not present a study on the assimilation of remotely sensed observations into hydrological models. As mentioned in the abstract (previously "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" and now "Water stored in the soil is isolated from the total water storage measured by GRACE whenremoving the contributions of both the surface reservoir, derived from satellite imagery and radar altimetry, and the snow estimated by inversion of GRACE measurements. The time variations of groundwater and permafrost are then obtained when removing the water content of the root zone reservoir simulated by hydrological models"), the introduction (previously "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 now "Then, water storage anomalies of surface waters and snow reservoir are removed from the TWS measured by GRACE to isolate the total soil storage (i.e., the sum of the soil, groundwater and permafrost storages) over 2003-2004 in the Lower Ob' basin"), and explained in the methodological section 3.3 Total soil and groundwater storages estimates. And then, we want to remind that this paper mostly presents 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. 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) the ups and downs of the TOPEX/Poseidon [which reference frame, tide-free, mean-tide or zero-tide was used] need to be considered more carefully than we find in the manuscript.

A more detailed and accurate description of the corrections applied to the altimeter range has been added to section 2.3 T/P-derived water levels: "All relevant environmental and geophysical corrections of the altimeter range measurements were applied. They include ionospheric, dry and wet tropospheric, solid Earth tide and pole tide corrections, and correction for the satellite's centre of gravity. Following Kouraev et al. (2004), corrections specific to open ocean environments such as ocean tides, ocean tide loading, inverted barometer effect and sea state bias were neglected". The common reference to all the water levels used in this study has been precised: "All the water levels are expressed with respect to the static GGM02C geoid model (Tapley et al., 2005).", moving this sentence from section 3.1 Monthly maps of water levels to section 2.3 T/P-derived water levels.

Minor Edits

All the minor edits suggested by Referee 1 have been taken into account: the reference to Muskett and Romanovsky has the right date (2009) in the text and the references section, "comsomonly" has been changed to "commonly", only "Ob' " is used in the

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manuscript, “orz” has been replaced by “of RZ”.

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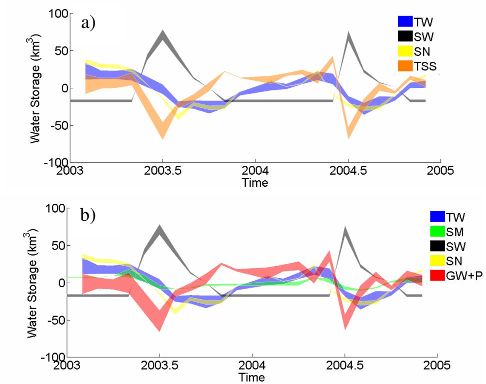

Figure 7. a) Monthly variations of TWS volume (blue), surface water volume from T/P radar altimetry and multisatellite inundation dataset (black), snow derived from GRACE measurements (yellow), TSS by difference between TWS and the other compartments (orange), Monthly variations of TWS volume (blue), 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.

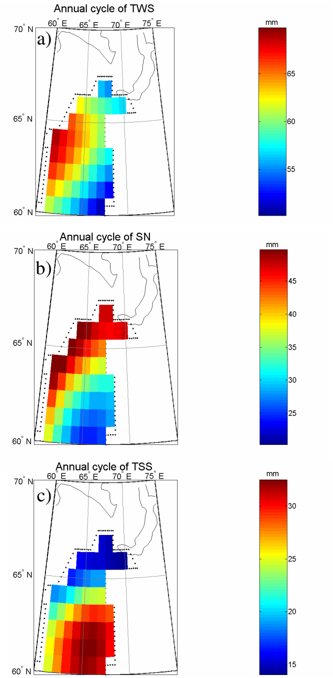

Figure 8. Amplitude of the annual cycle over 2003-2004: a) TWS from GRACE, b) Snow Water Equivalent (SWE) from GRACE, c) Total Soil Storage. Units: mm.

Fig. 2.

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