Answer to comments from reviewer 1:

Kalakoski et. al.: Validation of Copernicus Sentinel-3/OLCI Level 2 LAND Integrated Water Vapour product

The paper entitled 'Validation of Copernicus Sentinel-3/OLCI Level 2 LAND Integrated Water Vapour product by Niilo Kalakoski. Geophysical validation of the Integrated Water Vapour (IWV) from Sentinel-3 Ocean and Land Colour Instrument (OLCI) was performed as a part of "ESA/Copernicus Space Component Validation for Land Surface Temperature, Aerosol Optical Depth and Water Vapour Sentinel-3 Products" (LAW) project. The IWV was compared with reference observations from two networks: GNSS (Global Navigation Satellite System) derived precipitable water vapour from the SUOMINET network and integrated lower tropospheric columns from radio-soundings from the IGRA (Integrated Radiosonde Archive) database. The obtained results for cloud-free matchups overland with a high correlation against the reference observations SUOMINET as well as IGRA. Space based IWV have inherent uncertainties and need to be validated time to time basis before in operational or making the data in repository for future research. In that respect the present study have a high potential for publication after incorporation of the comments/suggestions as given below:

The authors thank the reviewer for the careful reading and constructive comments. Several of the main issues raised by the reviewer were deliberate choices in order to keep the paper concise. However, we also appreciate that clarification and extension is needed in several places, notably the algorithm and data selection descriptions.

Please find below our answers (in blue) to the comments presented (in black).

MAJOR REVISIONS:

No discussion of other satellites that provide IWV in the introduction (e.g. MODIS, SCIAMACHY, GOME-2, AIRS).

Discussion of IWV from other satellite instruments extended. Extended discussion can be found on lines 22-42.

Details about retrieval algorithm of Sentinel-3/OLCI Level 2 LAND Integrated Water Vapour product are missing and also give references i.e.

i) How does Sentinel-3/OLCI provide LAND IWV data?

ii) How is Sentinel-3/OLCI LAND IWV level2 data product generated?

iii) How is Sentinel-3/OLCI LAND IWV level2 data different from radiosonde (IGRA) and GNSS in measuring/estimating IWV?

iv) Are there any limitations of Sentinel-3/OLCI LAND IWV level2 data product based on former evaluation study (more literature reviews are needed).

v) What is the horizontal resolution of IWV derived from Sentinel-3 OLCI LAND IWV level2 data?

vi) Which method was used to identify cloud free pixels?

Description of the retrieval algorithm in Section 2 was extended to consider these questions.

Line-76: Give references.

We added reference to SUOMINET website to following sentence and moved the Ware et. Al. reference to this sentence. See lines 110-114 of the revised manuscript.

Section 3.1 & 3.2: You have used Radiosonde & GNSS data as reference for comparison with OLCI Level 2 LAND IWV. But the Radiosonde & GNSS based data also associated with errors. Explain the possible sources of errors in your analysis with references.

Description of error sources was extended in Sections 3.1 and 3.2.

For IWV matchups a macro pixel of 31 × 31 OLCI pixels (i.e. a surface of around 10 by 10 km) with central pixel over each reference station is extracted at each overpass.

What is horizontal resolution of OLCI IWV products and why you have selected 31x31 pixels? Have you applied any interpolation technique for resampling of OLCI IWV data over reference?

Horizontal resolution of full resolution OLCI IWV is 300 metres. 31 x 31 pixel area was chosen as a compromise between acquiring enough values around the closest co-location and the storage requirements. No interpolation was applied to OLCI products in this study. Sections 4.1 and 4.2 were clarified in the revised accordingly.

Specific Comments:

All ground-based measurements acquired in a time window of +/- 3 hours are considered.

It is not clear here in matchup criteria of time window of +/- 3 hours you considering for radiosonde (IGRA) or GNSS. Kindly mention time window for radiosonde (IGRA) for consideration of data along with which UTC data have been utilized for this study and same for GNSS also.

The description of selection criteria was clarified. 3-hour time window was used for the matchups with IGRA observations to allow for more matchups to be generated from relatively limited number of soundings. For the SUOMINET observations the more stringent 15-minute criterion was applied. Vast majority of soundings used here are launched just before 00UTC or 12UTC.

Missing satellite observations were only filtered from the database in the case of operational issues or radio frequency interference (RFI) contamination. How radio frequency interference (RFI) contamination occur in your data?

RFI contamination can occur when other satellites interfere with the transmission of the Sentinel-3 observations to the ground station. In OLCI, this can lead to a loss of a few data packets creating data gaps over a few rows. RFI contamination can occur roughly 10 times a month, each time impacting a few lines. Sentence was clarified (lines 139-140).

For all matchups, we applied an additional quality check according to quality flags. The matchups with failed inversion (WV_FAIL flag set) or with cloud warning flag (CLOUD), were discarded. For this study, you have chosen data from Sentinel-3 OLCI LAND IWV during cloud free pixel only then why again applied additional quality check. Please clarify.

The screening for the CLOUD flag here is the part where we select the cloud-free observations. The observation is called as cloud free, when none of the cloud flags (CLOUD, CLOUD_MARGIN, CLOUD_AMBIGUOUS) are set. The text about the selection criteria clarified accordingly (lines 146-147).

9. *For each matchup, the satellite-reference observation pair with smallest time difference was chosen. For SUOMINET, matchups with time differences larger than 15 minutes, or nominal error larger than 2 kg/m2 were not used.* Kindly give the references.

The data selection criteria are the same as in Kalakoski et. al. 2016. We added this reference in the revised version of the paper.

The selection criteria for SUOMINET were largely selected based on personal experience. Maximum time difference of 15 minutes was selected to avoid observations affected by short-term data gaps. SUOMINET observations are normally available at 30 minute intervals, thus the 15 minute maximum difference ensures that the selected observation comes from an unbroken sequence. Nominal error limit was chosen based on analysis of the distribution of nominal error values. Neither requirement is very strong and as a consequence this screening removes very few observations.

10. *The dispersal of the differences is considerably higher for IGRA matchups, partly due to longer time differences allowed, and the drift of the sondes during the ascent.* Higher differences may due to the radiosonde ascents drift and vertical extent will be different over different geographical domains. Similarly, the collocations matchups of clear sky pixel retrievals will vary and hence the differences values also vary latitudinal.

Thank you for your suggested explanation. Discussion of geographical variance of sonde drift was added to section 3.1 (lines 104-108) and to end of section 5.1.

Observed in SUOMINET comparisons, the bias reduction can be related to radiosonde data or to collocation criteria. General comparisons also indicate very good agreement between OLCI-A and -B.
What is retrieval algorithm of IWV of OLCI-A and -B. How bias can be reduce and related to radiosonde data.

Here we discuss the reasons for lower bias observed in radiosonde comparisons at very high IWV values. We clarified the text to avoid the confusion. New text reads "t*he dispersal of the* *differences is considerably higher for IGRA matchups, partly due to longer time differences allowed, and the drift of the sondes during the ascent*" (Lines 163-165).

Line120: *INLAND_WATER water pixels, representing rivers and lakes, similarly show wet bias and large dispersal.*
Give references.

The INLAND_WATER pixels were analyzed separately as part of this study, but the scatterplot is not shown here. The dispersal can be seen in figure 7 (of the initial submission). Following the recommendation of reviewer 2, the figure and the discussion of water pixels was removed from the revised manuscript.

The dependency observed for latitude and solar zenith angle is related to generally higher water vapour total columns seen in low latitudes and solar zenith angles,while the seasonal cycle is consistent with the over-presentation of northern hemisphere stations and higher total columns during summer months.

Give some prove or reference for this claim?

These are our interpretations from the data shown here. We stress this in the revised version. Timeseries and the discussion of the seasonal cycle was removed from the revised version as per recommendation by reviewer 2.

Line 161-168: *OLCI observations classified as water surfaces (WATER and INLAND flags, including TIDAL with WATER) considerably larger bias and dispersal than those classified as land surfaces (LAND flag, including TIDAL with LAND).*

OLCI observations in pixels data contains both sea and mountainous land together along with topographically diverse terrains around these stations may introduce large bias.

That is true. Unfortunately for this study, the meteorological stations are often located in "interesting" locations, presenting a problem for the representativeness of the station. Small footprint of the modern satellite instrument like OLCI can partially offset this issue. WATER pixels are not considered in the revised version of the manuscript, further mitigating this issue.

We added a note in the revised version.

Technical Corrections:

Line 90: May need prove reading carefully.

Section was rewritten to improve clarity.