FY2019 Progress Report To:

the

Japan Aerospace Exploration Agency

# Validation of GCOM-W1 products using global water and energy balance monitoring at the Murray-Darling Basin in Australia

Specification No: **JX-PSPC-511409**; Contract No: **19RT000312**

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# Executive Summary

This report presents the research activities and research outcomes for the project 'Validation of GCOM-W1 products using global water and energy balance monitoring at the Murray-Darling Basin in Australia' during JFY 2019. One of the main research activities aimed to continue operating the JAXA flux tower within the core validation site located in Yanco, New South Wales, Australia. This provides spatially distributed soil moisture data from across an AMSR2 sized footprint. It was proposed that during JFY 2019, this project would make significant independent and collaborative contributions to:

i) Continuing the validation of the AMSR2 soil moisture product against in-situ observations.

ii) Intercomparing the AMSR2 soil moisture product with complimentary satellite soil moisture products from other missions, such as SMAP.

iii) Validating the vegetation water content (VWC) product against a) field sampling and b) complimentary satellite (optical and passive) derived VWC.

Due to the unavailability of research product of the AMSR2 VWC, the 3rd target was changed to validating the land surface model simulated soil moisture and flux data using AMSR2 products. According to the information provided by JAXA, the AMSR2 VWC research product will be available in early 2020. Therefore the 3rd target will be accomplished in JFY 2020.

Similar to previous years, for JFY 2018 to JFY 2019, AMSR2 L3 product (10km & 25km) still underestimates the soil moisture when compared with the tower measurements and representative stations, especially during wet season.

Compared to JFY 2015 to JFY 2016 and JFY 2017 to JFY 2018, the AMSR2 soil moisture validation statistics in JFY 2018 to JFY 2019 perform better in terms of RMSE and bias, but worse in correlation.

The land surface model assimilated soil moisture using ASCAT and SMOS has overall good agreement with the AMSR2 SM product, with an RMSD of 0.06 $m^3/m^3$; assimilated latent heat/sensible heat also match very well with tower data.

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# Chapter 1: Introduction

This report presents a range of research activities and research outcomes of the project Validation of GCOM-W1 products using global water and energy balance monitoring at the Murray-Darling Basin in Australia during JFY 2019. The project seeks to continue operating the JAXA flux tower within the core validation site located in Yanco, New South Wales, and provide spatially distributed soil moisture data from across an AMSR2 sized footprint. Importantly, this project will also make significant independent and collaborative contributions to i) continuing the validation of the AMSR2 soil moisture product against in-situ observations; ii) Intercomparing the AMSR2 soil moisture product with complimentary satellite soil moisture products from other missions, such as SMAP; and iii) validating the land surface model simulated soil moisture and flux data using AMSR2 products.

During JFY2019, the main research activities include tower inspection and faulty sensor replacement. Other activities include regular site visit and maintenance of the JAXA flux tower, data downloading and processing. The processed soil moisture data was used to validate the 10-km and 25-km resolution AMSR2 soil moisture products. On the other hand, soil moisture from 2 assimilation experiments at the JAXA tower location are validated against tower data and compared with AMSR2 soil moisture product. Assimilated latent heat and sensible heat is also validated against tower data.

Due to the delay in obtaining the AMSR2 Vegetation Water Content (VWC) Research product, validation of this data against calculated VWC from MODIS vegetation indices, and against field sampling collected from SMAPEx-4 and SMAPEx-5 field campaigns at Yanco area, will be moved into the research outcomes of the following year.

# Chapter 2: Flux Tower Maintenance, Tower Inspection and Sensor Replacement

## 2.1 Flux Tower Maintenance for JFY 2019

Regular site maintenance completed during 2019 was undertaken by a dedicated Monash University Field Technician. This occurred every 1-2 months and included the following activities:

i) cleaning of all environmental sensors within the enclosure;

ii) insect control and grass cutting;

iii) downloading of data and battery health checks.

It is important to note that current battery performance for all loggers is working well. However, to keep in mind that they are already out performing normal battery life. Therefore, replacements/upgrades should potentially be considered in future budgets.

## 2.2 Tower Inspection

It was discovered in the OzFlux guidelines that this tower is recommended to be inspected on an annual basis and had not be done for some time (http://www.ozflux.org.au/events/july2012/Friday/8_DarrenHockingTowerSafety.pdf).

Therefore, a local contractor was sourced to complete the works as provided for the in JFY2019. The Wave1 company (Rowville, Victoria, Australia) provided a quote for a full inspection of tower structure, guy wires and anchor blocks. This quote also included the replacement of 2 environmental sensors at the top of the tower (16m above ground) to be completed during inspection. These sensors had been identified as giving erroneous data, and JAXA had recently provided replacement instruments to be installed.

Wave1 was secured as contractor and all works were completed on December 3rd, 2019. Monash University staff were onsite during that time to supervise the works and all went successfully.

According to the inspection report provided by Wave1, the following conditions about the tower are found/fixed:

i) The Mast itself is in good condition. All tower hardware was confirmed to be adequately tensioned.

ii) The Ladsaf system is in good condition and has been checked and recertified. (The certification plate was not available on site to be re stamped). A new pressure washer was installed and tightened to its shear strength.

iii) The guy wires, turnbuckles and associated rigging are in good condition. The Bow shackles at the guy attachment points on the Mast did not have any mousing. This was rectified during the inspection. The guy wire tensions were low and re-tensioning was conducted.

iv) The footings appear to be in good condition.

v) The antenna mounts and brackets are all in good condition.

Figure 1: View of the Mast of Tower

Figure 2: Bow Shackle with new mousing

Figure 3: Ladsaf spring inspection – Ladsaf system in good condition

Figure 4: Mast base

Figure 5: Guy Wire inspection – re-tensioning conducted

## 2.3 Sensor Replacement

During tower inspection, sensors that were replaced included:

i) 2 x Campbell Met One 034B Windset (at 2m and 16m above ground) (Figure 6),

ii) 1 x HMP155A temperature and humidity sensor (at 16m above ground) (Figure 8 and Figure 7) and 1 x TRIMEPICO32 soil moisture sensor (at 10cm below ground) (Figure 9).

All replaced sensors are currently functioning well, as shown in the plots of updated (raw) data below.

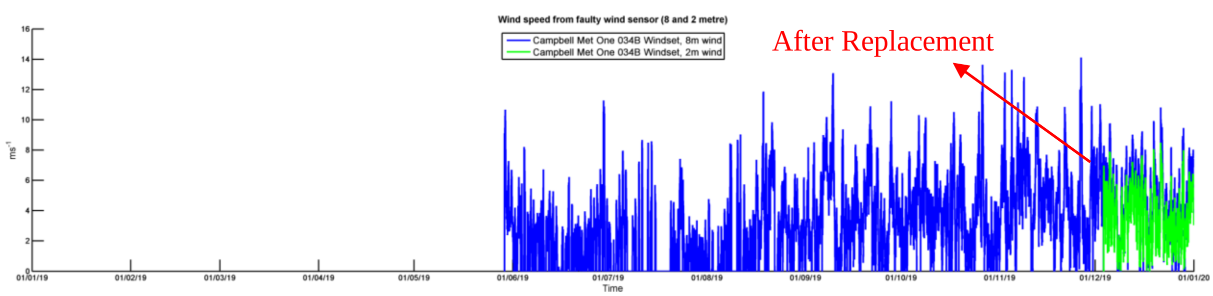


Figure 6: Campbell Met One 034B Windset (at 2m and 16m above ground)

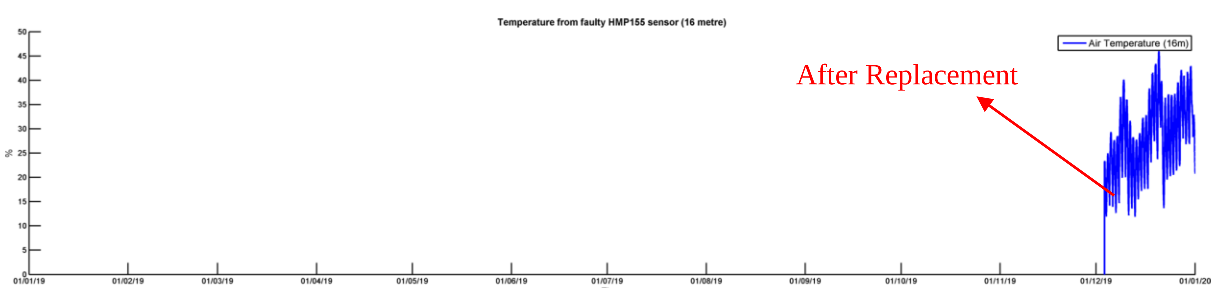


Figure 7: Temperature measurements from HMP155A temperature and humidity sensor (at 16m above ground)

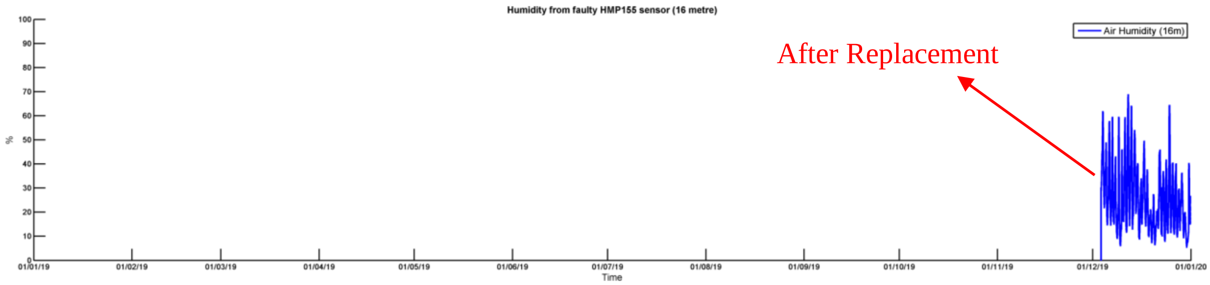


Figure 8: Humidity measurements from HMP155A temperature and humidity sensor (at 16m above ground)

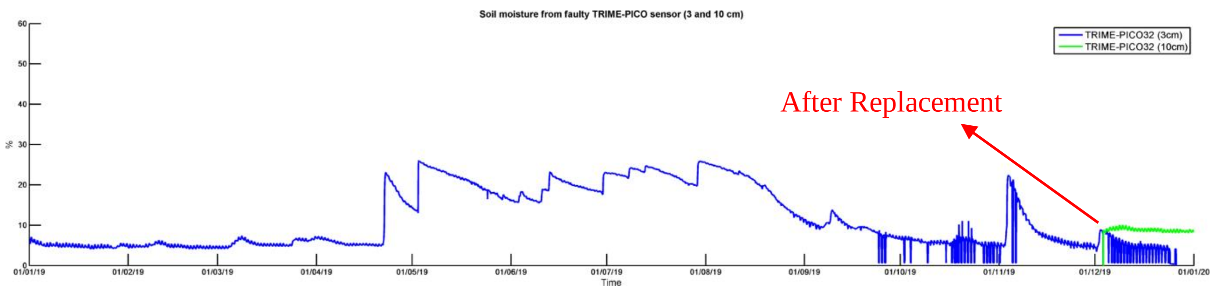


Figure 9: TRIMEPICO32 soil moisture sensor (at 3cm and 10cm below ground)

In addition to the already replaced sensors, it has now been discovered that Windset sensor2 (at 8m above ground) has been having some problems (Figure 6). Supplementary to that, TRIMEPICO32 (at 5cm below ground) seemed to drop out on the 25th December 2019 (Figure 9). Both of these sensors will be monitored over the coming field visits.

ASSH_T weather station remains functioning well. As stated in the last report that the HMP155A temperature and humidity sensor was to be moved to the tower, this turned out to be unnecessary since JAXA kindly provided another replacement to use.

Current conditions of the tower enclosure and surrounding area are extremely dry. There has not been significant moisture since late 2016 and grass growth is slow/minimal all year round. There have been no issues whatsoever at accessing the site for a number of years.

Calibration of the Open Path $CO_2$/$H_2O$ Gas Analyzer (LI-7500A) is planned to be undertaken in March 2020. Replacement scrubber chemicals will be ordered from LICOR and once they have been received, technicians plan to remove equipment and calibrate before returning within 48 hours.

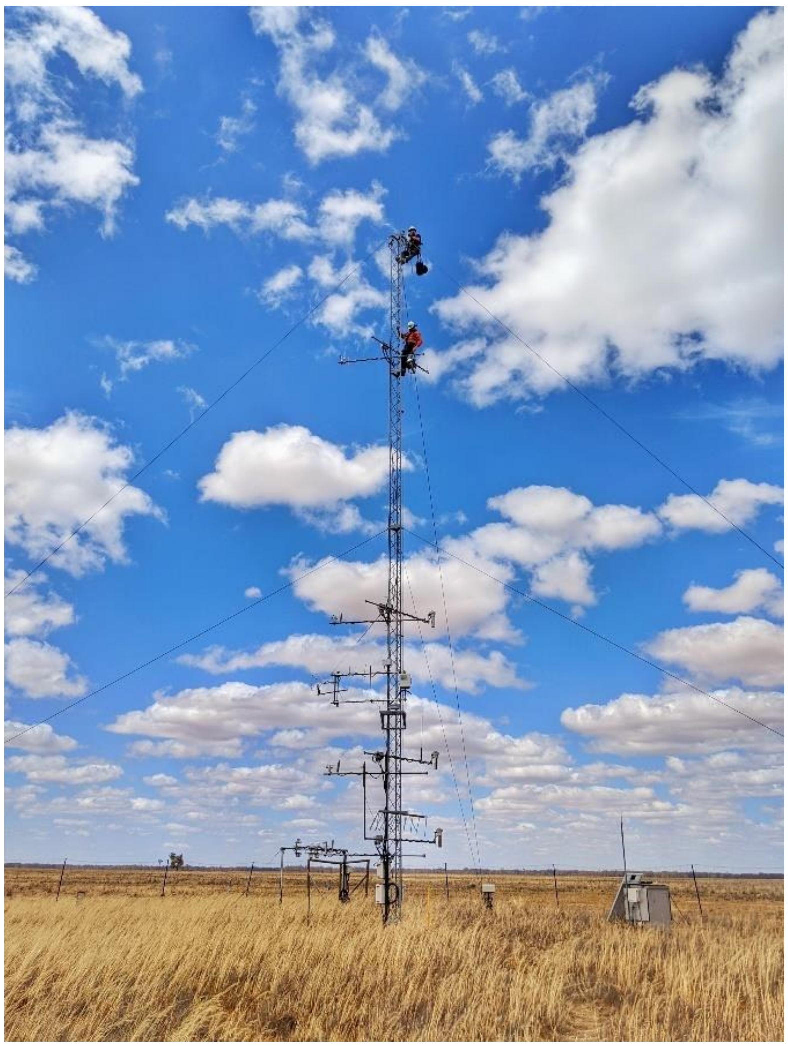

Figure 10: Wave1 staff undertaking tower inspection and sensor replacement

Figure 11: Replacement of TRIMEPICO32 at 10cm below ground level

Figure 12: Dry conditions at the base of the tower whilst cutting grass.

# Chapter 3: Data Archive

## 3.1 JAXA Tower Data Archive

Half-hourly measurements from the JAXA flux tower are uploaded from the JAXA station to a Monash server on a weekly basis. The 10 Hz data are downloaded from the logger during monthly site visits. All raw data are downloadable from oznet.org.au.

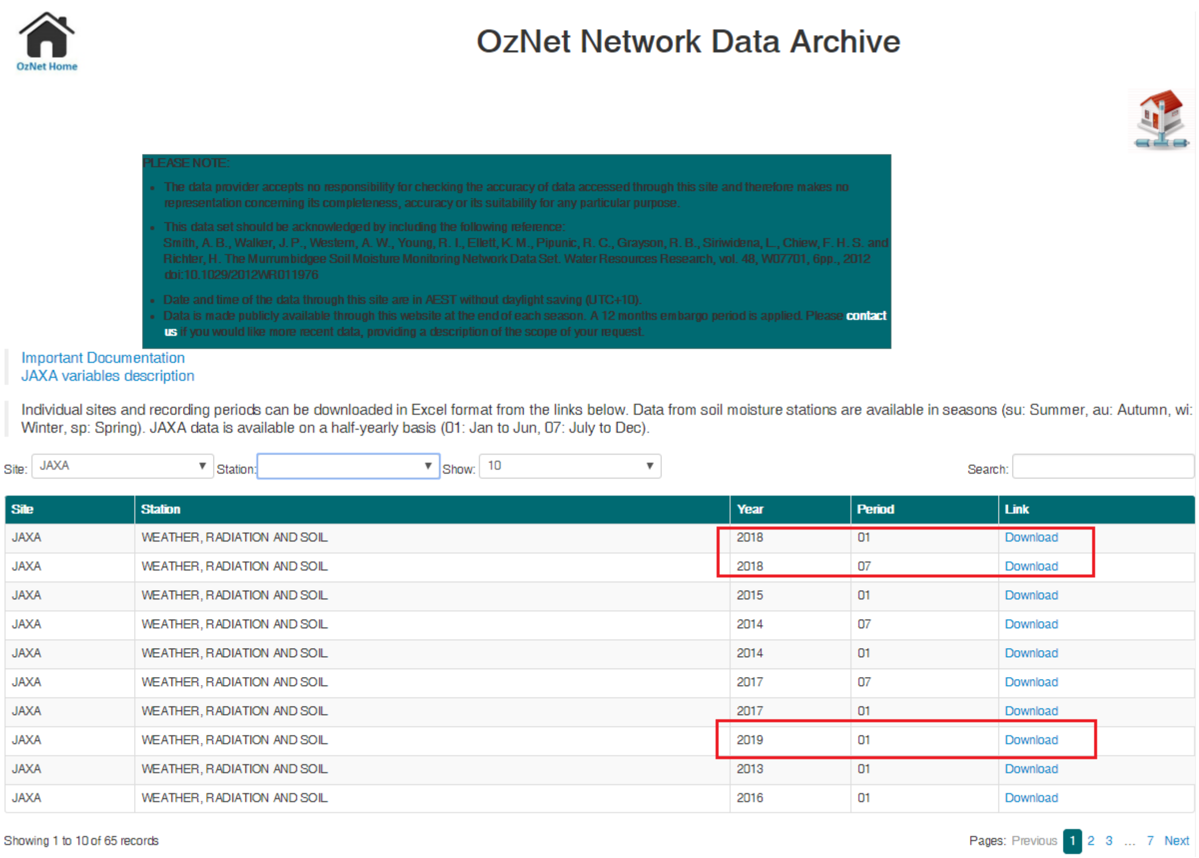


Figure 13: JAXA data download interface on http://www.oznet.org.au/mdbdata/mdbdata.html.

Based on the recent proposal, simple quality checks will be applied to these data to remove data which are out of range. Figures below show some of the key data collected in 2019 from the JAXA tower.

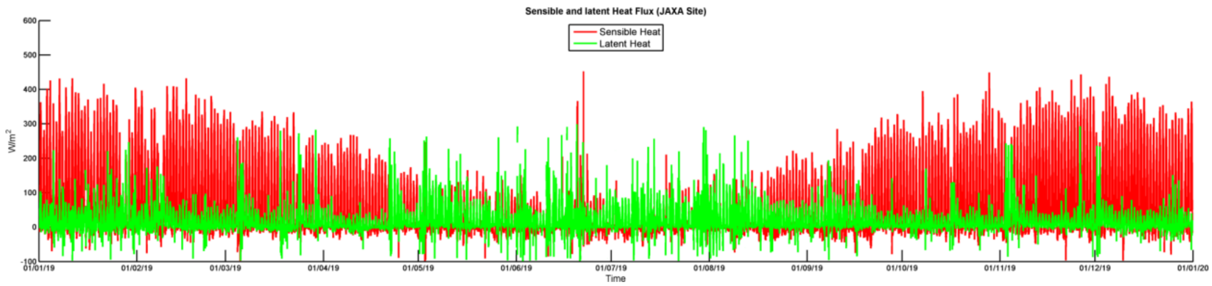


Figure 14: Heat fluxes measured at JAXA Tower for 2019.

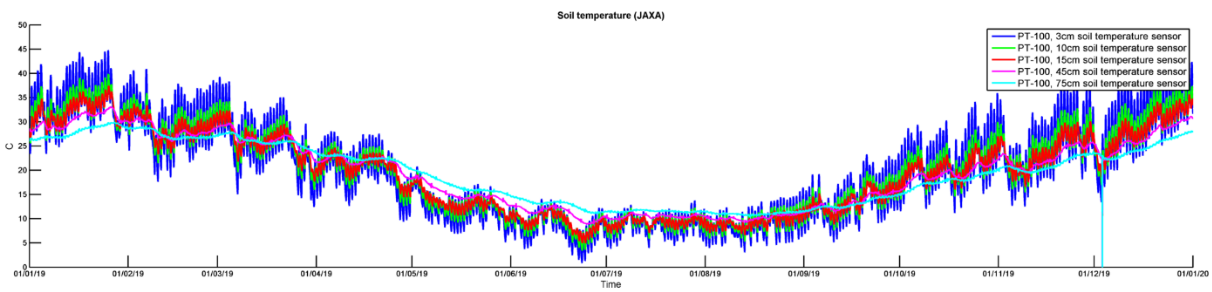


Figure 15: Soil Temperature at JAXA Tower for 2019.

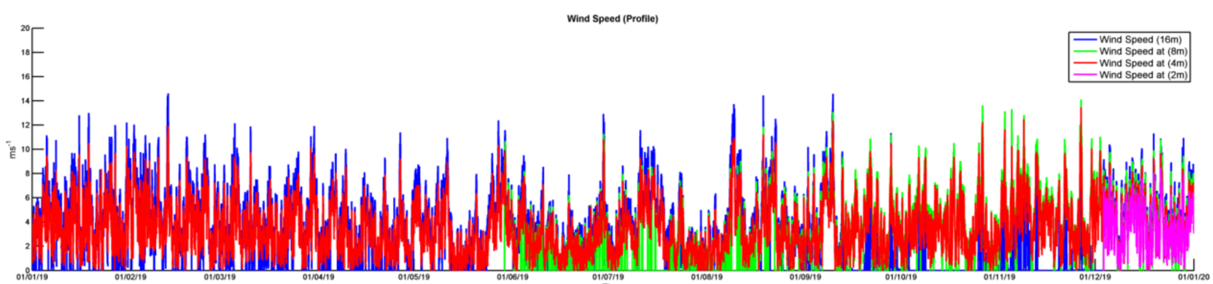


Figure 16: Wind speed at JAXA Tower for 2019.

## 3.2 Real-time Figures Archive

Real-time figures from the flux tower is also produced and available at http://www.science.uwa.edu.au/centres/land/yanco. The website is maintained by Prof. Jason Beringer' s team in Faculty of Science, the University of Western Australia (jason.beringer@uwa.edu.au).

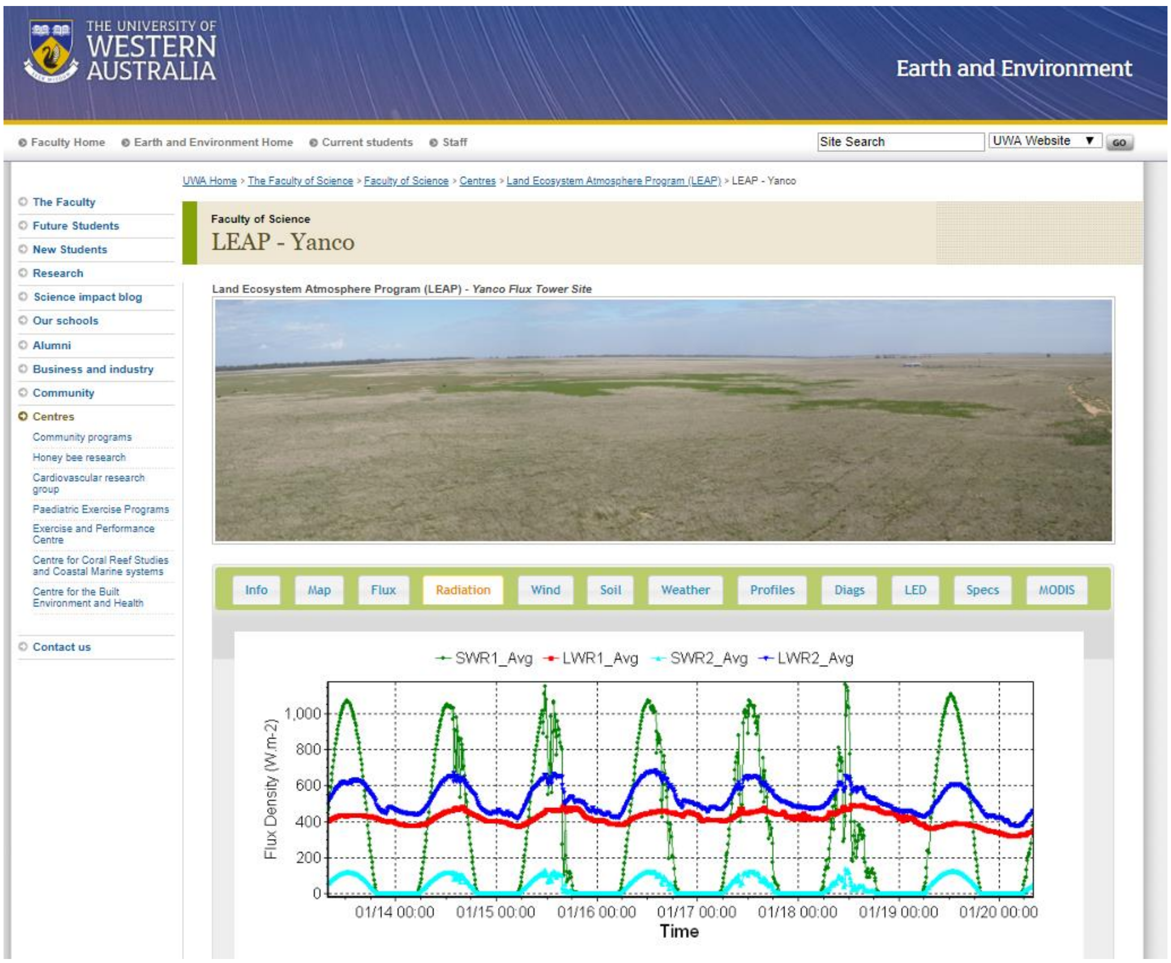


Figure 17: Real-time tower data interface on http://www.science.uwa.edu.au/centres/land/yanco.

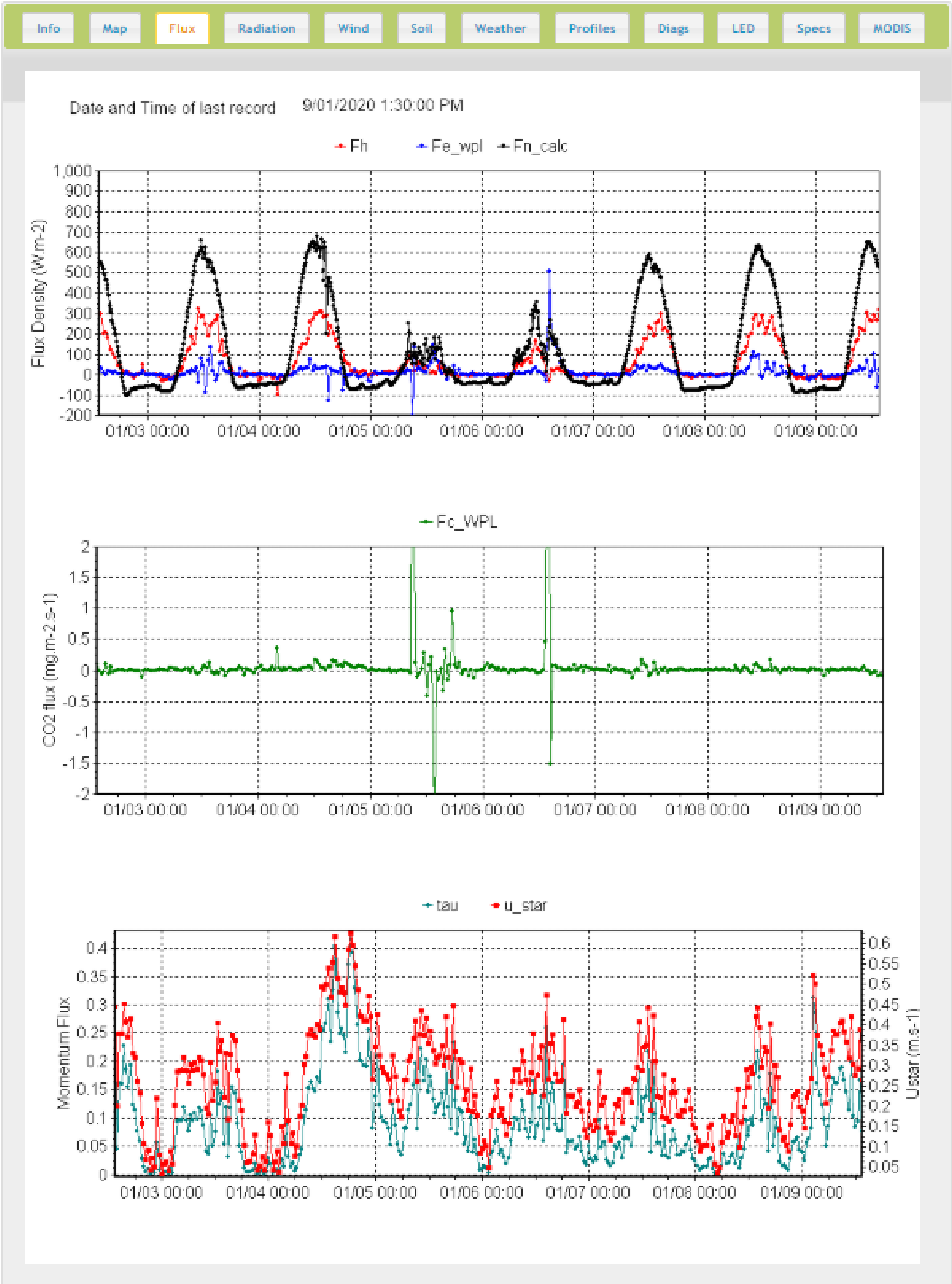


Figure 18: Examples of real-time figures for fluxes.

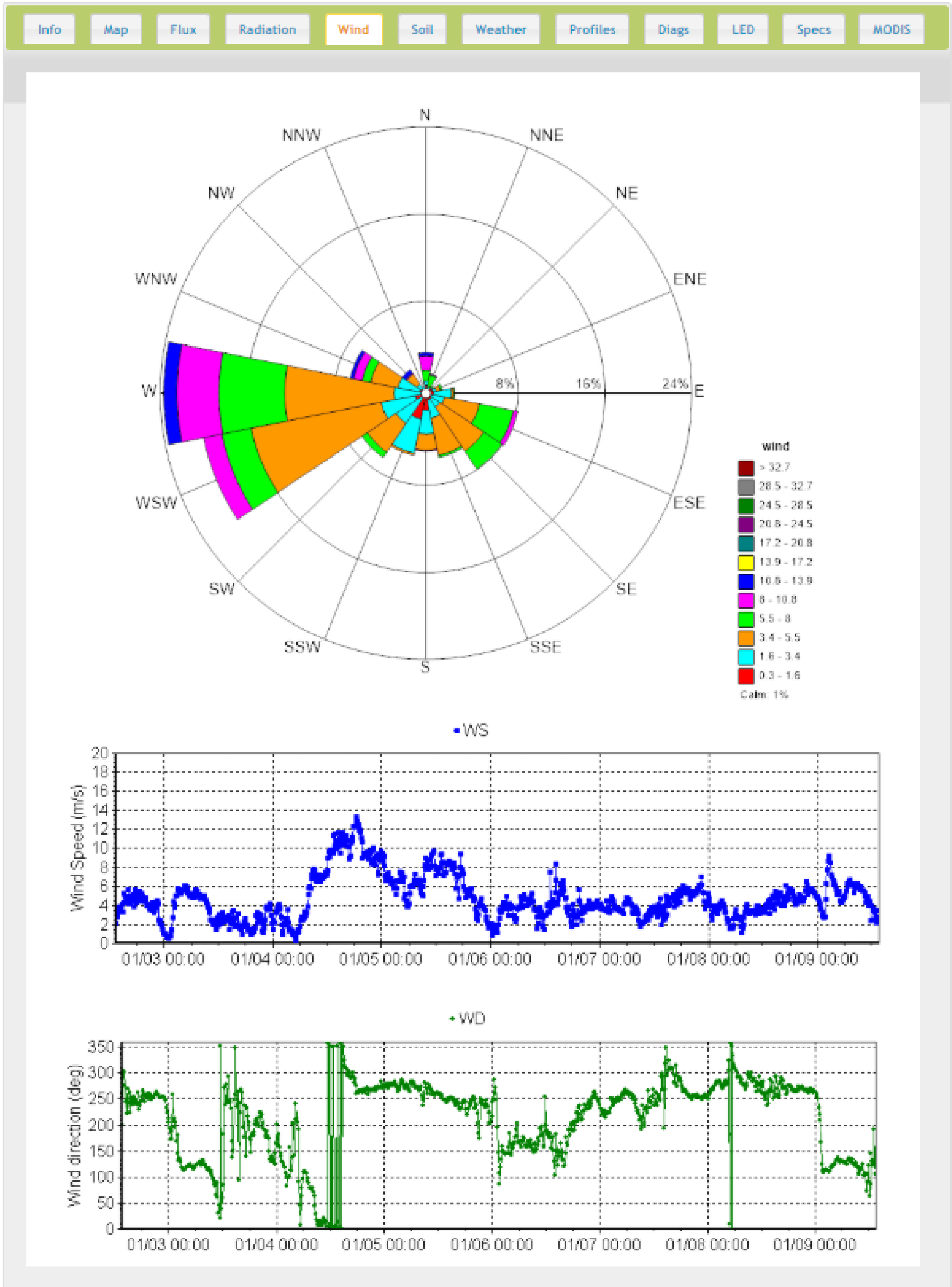


Figure 19: Examples of real-time figures for wind speed and wind direction.

## 3.3 OzNet monitoring network data

Soil moisture and soil temperature over 20-min interval of measurements from the OzNet monitoring stations are collected from each station. All raw data have been archived and downloadable at http://www.oznet.org.au.

Data were separated and named according to the southern hemispheric seasons, i.e. spring (September – November), summer (December – February), autumn (March – May) and winter (June – August). Simple quality checks have been applied to these data whereby out of range values have been removed.

# Chapter 4: AMSR-2 L3 SMC products

## 4.1 Site Description – the Murrumbidgee Catchment

The Murrumbidgee catchment is located in southern NSW, Australia. It is bordered by the Great Dividing Range to the east, the Lachlan catchment to the north, and the Murray catchment to the south. The Murrumbidgee Catchment exhibits a significant spatial variability in climate, soil, vegetation and land cover because of its distinctive topography (Figure 20). Due to the diversity within this area, the large amount of complementary data from long-term monitoring sites, and past airborne field experiments, this region is an ideal test-bed for the comprehensive validation of satellite soil moisture from missions such as GCOM-W1 and is highly complementary to validation sites in Mongolia and Thailand. Moreover, considering the size of the satellite footprint, there are regions in the catchment that are relatively homogeneous in regard to climate, soil type, vegetation, and consequently radiometric response (Rüdiger et al., 2011) when compared to many other countries.

Temporal climatic variations of the catchment are primarily associated with elevation, varying from semi-arid in the west to temperate in the east. The total average annual rainfall for the entire Murrumbidgee River catchment is about 530 mm, with a mean annual precipitation of 300 mm in the west and about 1,900 mm towards the east in the Snowy Mountains. The actual evapotranspiration is equivalent to precipitation in the west but represents only half of the precipitation

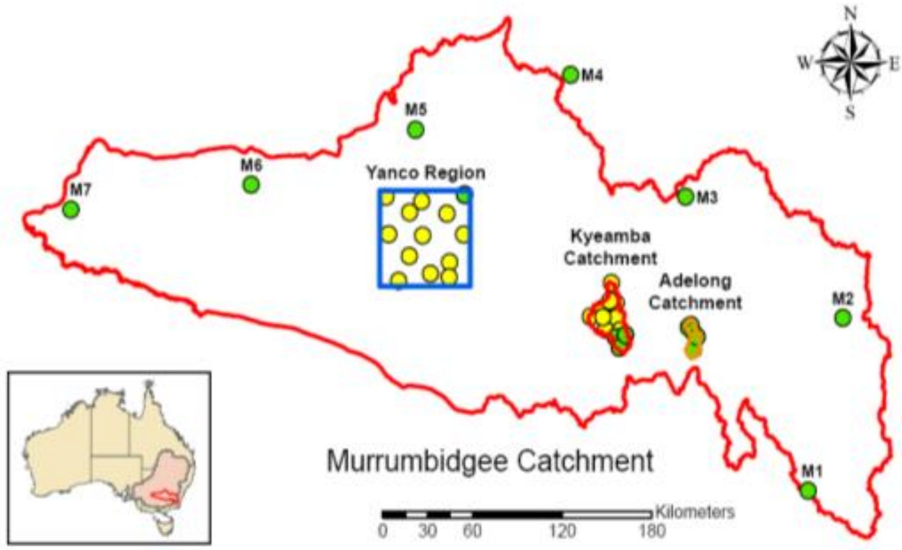


Figure 20: Location of the Yanco core validation site within the Murrumbidgee Catchment. Also shown is the location of the Murrumbidgee Catchment within the Murray-Darling Basin (inset) and the locations of sparse network soil moisture stations.

in the east. Long term averaged precipitation data for the Murrumbidgee Catchment shows a relatively constant rate of rainfall across the year, with a slight increase in winter. The Murrumbidgee catchment is characterised by plains in the west with an elevation around 50 m, to steep mountainous regions towards the east with elevations more than 2,100 m in the Snowy Mountains. Soils in the Murrumbidgee Catchment vary from sand to clay, with the western plains being dominated by finer-textured soils and the eastern slopes being dominated by medium-to-coarse textured soils (McKenzie et al., 2000).

Land use in the catchment is predominantly agricultural with the exception of steeper parts, which are dominated by a mixture of native eucalypt forests and exotic forestry plantations. Agricultural land use varies greatly in intensity and includes pastoral, more intensive grazing, broad-acre cropping, and intensive agriculture in irrigation areas along the mid-lower Murrumbidgee. Grazing is predominant in the west and scattered in the east, whereas dryland cropping dominates the mid Murrumbidgee catchment.  Irrigation sites are mainly located in western part of the Yanco core validation site. The catchment is comprised of about 52% pasture, followed by about 21% arable and 18% silvicultural land use. The other land use types represent less than 9% of the total catchment area.

## 4.2 Site Description – the Yanco Site

The Yanco area is a 60 km x 60 km area located in the western plains of the Murrumbidgee Catchment where the topography is flat with very few geological outcroppings (Figure 21). Soil types are predominantly clays, red brown earths, transitional red brown earth, sands over clay, and deep sands. Approximately one-third of the core validation site is irrigated during summer when sufficient water is available. The Coleambally Irrigation Area (CIA) is a flat agricultural area of approximately 95,000 hectares that contains more than 500 farms. The principal summer crops grown in the CIA are rice, corn, and soybeans, while winter crops include wheat, barley, oats, and canola. Rice crops are usually flooded in November by about 30 cm of irrigation water.

A total of 24 surface soil moisture sites were installed in late 2009 to develop a nested soil moisture monitoring configuration for the SMAP mission at scales of approximately 3 km, 9 km and 36 km. These stations continuously monitor the soil moisture over the 0-5 cm layer with a Hydraprobe and soil temperature sensors (Unidata® 6507A/10) at 1, 2.5 and 5cm depths. The 24 sites are concentrated on two 9 km x 9 km focus areas (areas YA and YB), corresponding to two pixels of the SMAP grid at which the active passive soil moisture product (SMAP L3_SM_A/P product) was to be produced. Finally, 10 of the sites within areas YA and YB are

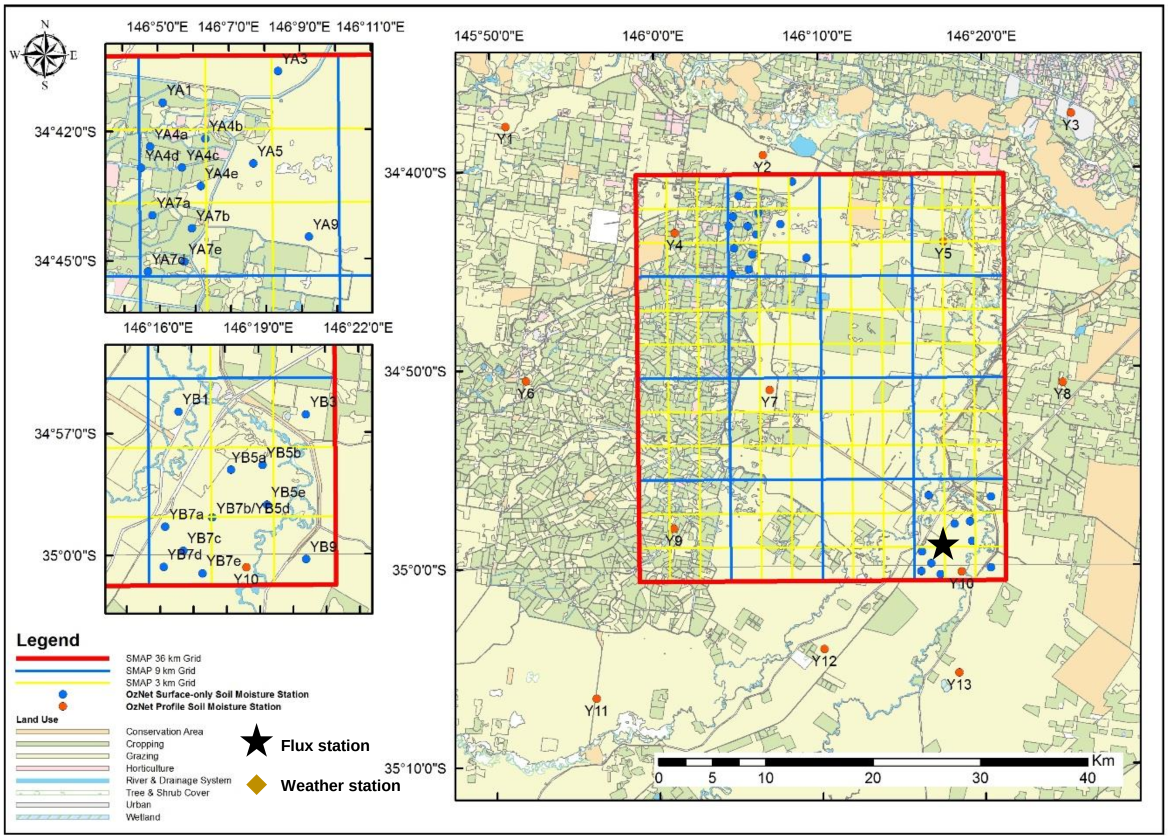


Figure 21: Locations of the JAXA flux station, weather station and soil moisture monitoring stations within the Yanco core validation site. Also shown are the YA and YB focus areas with intensive soil moisture stations, and the locations of intensive ground sampling areas.

concentrated on a further two 3 km x 3 km sub-areas (each) with at least 4 stations measuring the distribution of soil moisture across each, corresponding to a total of four of the SMAP radar pixels (see Figure 2 for details of the YB area). Unfortunately, the SMAP radar failed shortly after commissioning. However, sentinel data are being used to replace the SMAP radar observations for locations such as the Murray Darling Basin.

This intensive network is also an ideal core validation site for AMSR2, as it i) monitors soil moisture across an AMSR2 sized pixel with approximately 30 stations, and ii) can be used to validate AMSR2 downscaling algorithms through the nested sampling design and supplementary intensive ground sampling activities that have been undertaken. Moreover, extensive airborne data sets and supplementary ground data (see www.nafe.unimelb.edu.au; www.moisturemap.monash.edu.aaces; www.smapex. monash.edu) have been used to assess the representativeness of soil moisture sites for each of the 9 km x 9 km focus areas (areas YA and YB), corresponding to two pixels of the SMAP products at 3 km for radar, 9 km for radar-radiometer and 36 km for radiometer pixels (Yee et al. 2016). These stations have also been used to validate AMSR2 soil moisture products based on the JAXA and LPRM algorithm of different versions, and SMOS soil moisture products (Yee et al., 2016), and provide a perfect source of data for the passive-passive downscaling work proposed here.

## 4.3 AMSR2 Level 3 soil moisture product

The AMSR2 L3 soil moisture product was downloaded from the GCOM-W1 Data providing Service (the G-Portal: [https://gportal.jaxa.jp/gpr/](https://gportal.jaxa.jp/gpr/)). To cover the whole period in which AMSR2 data is available, the analysis covered a time series from July 2012 to November 2019. Both the high resolution 10-km product and the low resolution 25-km product were considered in the analysis. The product identifier for the 10-km and 25-km resolution data products are 'GW1AM2_YYYYMMDD_01D_EQMD_L3SGSMC**H**F3300300' and 'GW1AM2_ YYYYMMDD_01D_EQMD_L3SGSMC**L**F3300300', respectively.

The AMSR2 pixel in which JAXA tower (-34.99S, 146.29E) is located was extracted. The pixel location of the L3 SM data scene is Row 1250, Column 1463 for the 10-km product, and Row 500, Column 586 for the 25-km product. The pixel boundaries

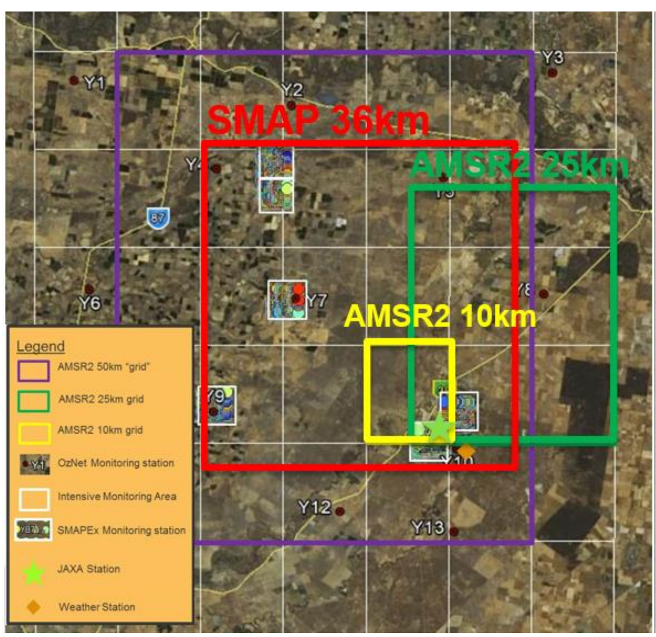


Figure 22: Location of the 10-km and 25-km AMSR2 L3 SMC pixel, SMAP 36-km pixel with respect to the flux tower location.

with respect to the flux town location is shown in Figure 22.

The time series of the AMSR2 Level 3 SMC 10-km and 25-km products are shown in Figure 23. Comparing with 2015-2016, 2017-2019 experienced a dryer condition throughout the period. But the higher values of 2018-2019 are more scattered. The wet season (May to August) in 2017-2019 is less obvious and has less extreme in

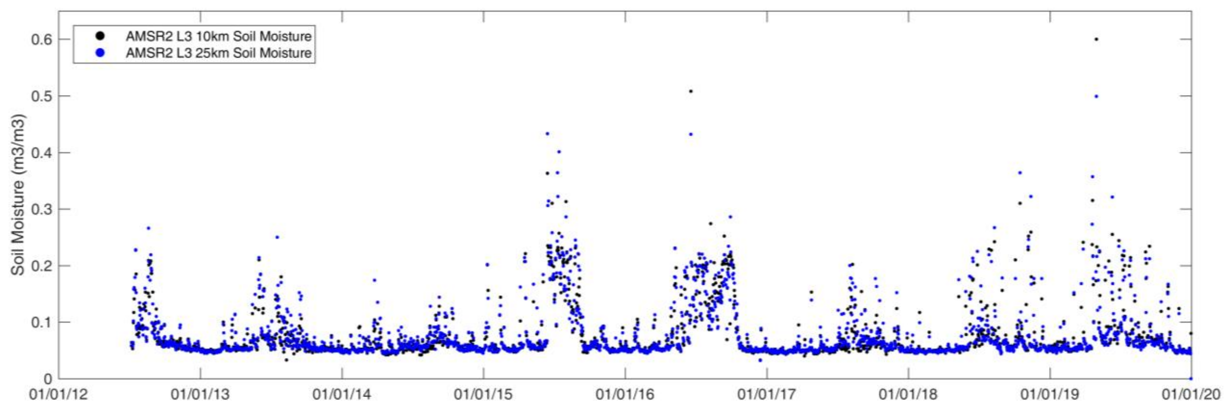


Figure 23: Time series of the AMSR2 L3 10-km and 25-km soil moisture in the Yanco site.

rainfall events. It can also be seen the high-resolution soil moisture almost coincide with the low-resolution data during the whole period, especially during the dry season. For the wet season, however, the low-resolution soil moisture has a slightly larger dynamic range. This could be due the reason that 25-km pixel contains a larger area and thus include mixed land cover types such as pasture, crops and forest, while within the 10-km pixel it is almost pasture.

Figure 24 shows the box plots of the AMSR2 L3 low- and high- resolution soil moisture. It is seen that most of data fall in the range of approximately 0.04 $m^3/m^3$ to 0.12 $m^3/m^3$ and the median value is only slightly above 0.05 $m^3/m^3$. Very few data exceed 0.2 $m^3/m^3$ which mostly happened in the winter season of 2015-2016 and 2018-2019, with the highest reaching 0.6 $m^3/m^3$.

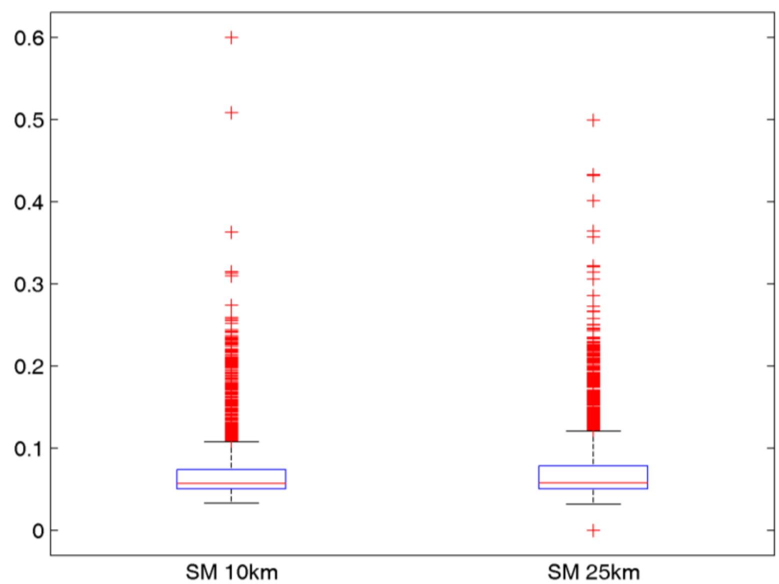


Figure 24: Box plot of the AMSR2 L3 10-km and 25-km soil moisture in the Yanco site.

# Chapter 5: Validation of AMSR-2 L3 SMC products

## 5.1 Time Series Plots

The AMSR2 L3 low- and high-resolution soil moisture products are validated against 1) the in-situ soil moisture measurements from the JAXA flux tower, 2) in-situ soil moisture measurements from representative OzNet stations and 3) SMAP observations.

Figure 25 shows a time series plot of the comparison of AMSR2 SM against flux tower SM from July 2012 to December 2019. On the flux tower, soil moisture sensor was installed at 3 cm depth below ground. It can be seen that the AMSR2 products (black for 10km and blue for 25km) are underestimating the tower soil moisture (red) in general. The correlation is relatively higher during the dry period of all years. Compared to tower SM, similar with previous years, in 2018-2019, lower values match better than the higher values. For 2018-2019, there was clear gap between tower and AMSR2 in wet season, similar to 2015-2016. There is also a clear trend of increasing and decreasing in tower SM throughout the wet season, while trend is not clear in the AMSR2 product.

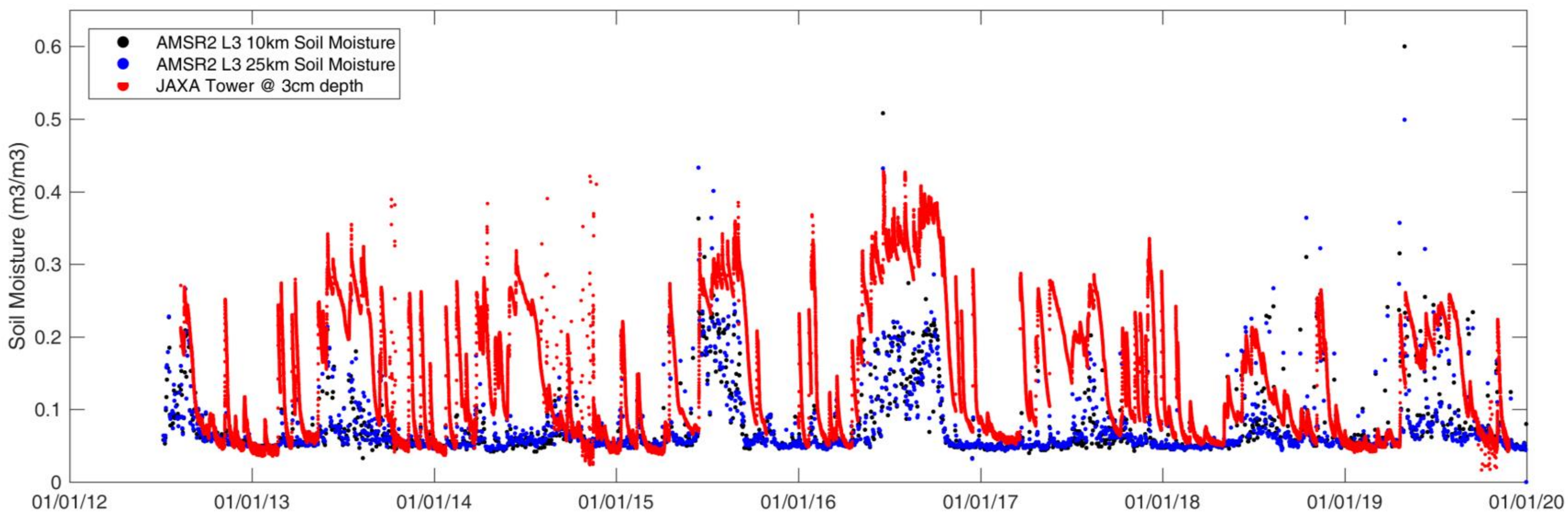


Figure 25: Time series plot of AMSR2 L3 10- and 25-km soil moisture product against JAXA flux tower soil moisture measured at 3-cm depth.

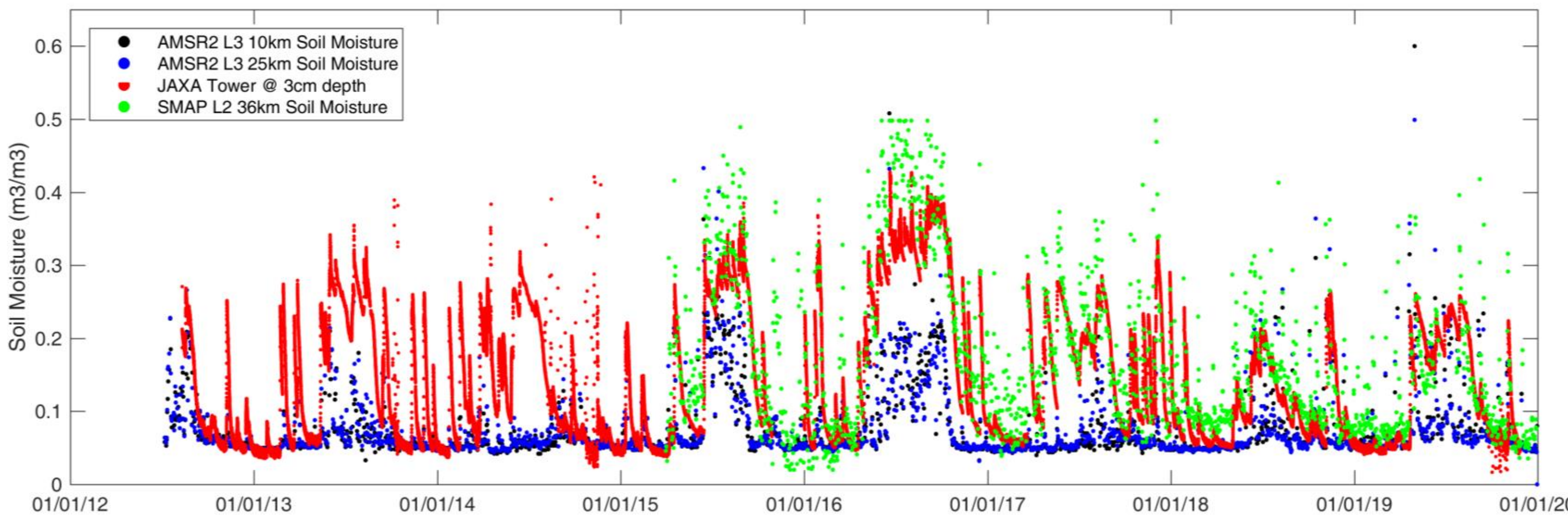


Figure 26: Same time series plot as Figure 25 with added SMAP L2 36km soil moisture product.

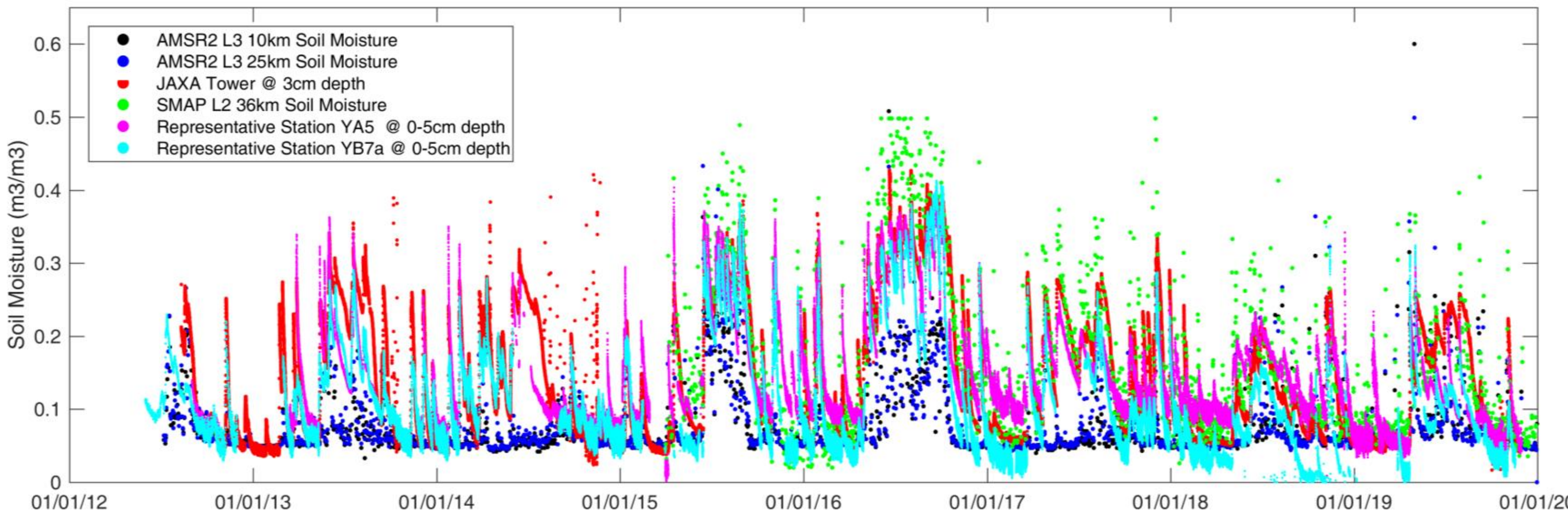


Figure 27: Same time series plot as Figure 26 with added representative stations YA5 and YB7a soil moisture.

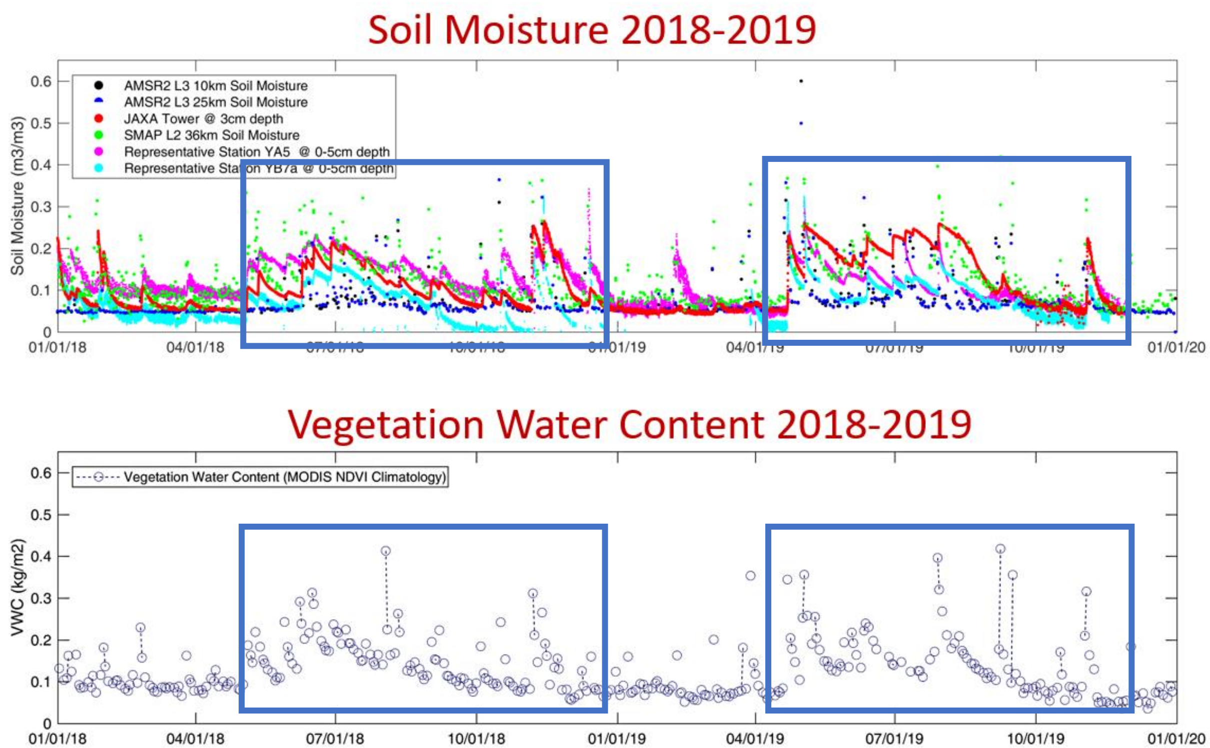


Figure 28: Soil moisture time series plot during 2018-2019 in comparison with VWC for the same period.

Figure 26 added the Soil Moisture Active Passive (SMAP) L2 36km (passive-only algorithm) product to Figure 25. The product was retrieved from L-band (1.4 GHz) brightness temperature observations. SMAP has a larger footprint of 36 km compared with AMSR2. It can be seen that the SMAP product (green) matches better with tower soil moisture compared to AMSR2 itself, especially for wet seasons. For dry season, however, SMAP overestimates the soil moisture 'truth' while AMSR2 matches slightly better. As it has also been widely demonstrated in the past that low frequency (L-band) has higher sensitivity to the moisture content variation and more capable to retrieve accurate surface soil moisture, it is suggested that the SMAP product should be closer to the ground 'truth', Currently, the work of comparing also with SMAP 9km and 3km products against tower measurements is also underway.

Figure 27 added the soil moisture from OzNet representative stations YA5 (pink) and YB7a (sky blue) to Figure 26. The comparison of the AMSR2 products against the OzNet stations shows similar results as above. It can be seen that YA5, representing the 36km regional area (SMAP pixel), is generally wetter, and matches better with SMAP SM product; YB7a, representing the YB area, is generally drier and matches better with AMSR2 SM product. Except that the OzNet station measurements represent an average value of the surface soil profile from 0 to 5 cm, there is one more reason: The soil moisture retrieval algorithm of the AMSR2 L3 product is based on the brightness temperature (TB) observation at 10 GHz (V, H) and 36 GHz (V). The microwave signal at such frequencies was emitted from the very top of the ground surface (less than 1 cm depth) and was relatively more sensitive to the overlaying vegetation compared with lower frequencies, while the tower moisture sensor and the OzNet sensor were measuring the soil moisture at a deeper layer of 3 cm.

As also mentioned in the annual report of JFY 2018, one possible way for improving the AMSR2 soil moisture product is through applying a simple regression of itself against in-situ measurement based on the historical data profile. This regression could be set to apply to the original product once soil moisture exceeds certain level, e.g. 0.1 $m^3/m^3$, beyond which the product/in-situ discrepancy starts to become more pronounced.

Figure 28 shows the soil moisture time series plot during 2018-2019 in comparison with VWC for the same period. Looking at the two years' data only, it is more obvious that the accuracy is lower during wet seasons. The VWC derived from MODIS 10-year NDVI climatology is also plotted to compared with the soil moisture trend. Here the VWC trend matches well with the soil moisture trend; the peaks of VWC also correlate well with the soil moisture peaks. Since the AMSR2 soil moisture was retrieved from C-band, which is a higher frequency, the signal is more affected by the vegetation layer and thus it is more difficult to decouple the effect of vegetation from SM. Therefore, it is less sensitive to the soil moisture change.

## 5.2 Scatter Plots and Statistics

The AMSR2 L3 soil moisture product at 10-km resolution are also plotted in Figure 29 as scatters against soil moisture observations from tower, SMAP, station YA5 and YB7a, respectively. Is it seen that the AMSR2 L3 product has an underestimation when compared with all four different references, with a negative bias ranging from 0.01 $m^3/m^3$ to 0.07 $m^3/m^3$.

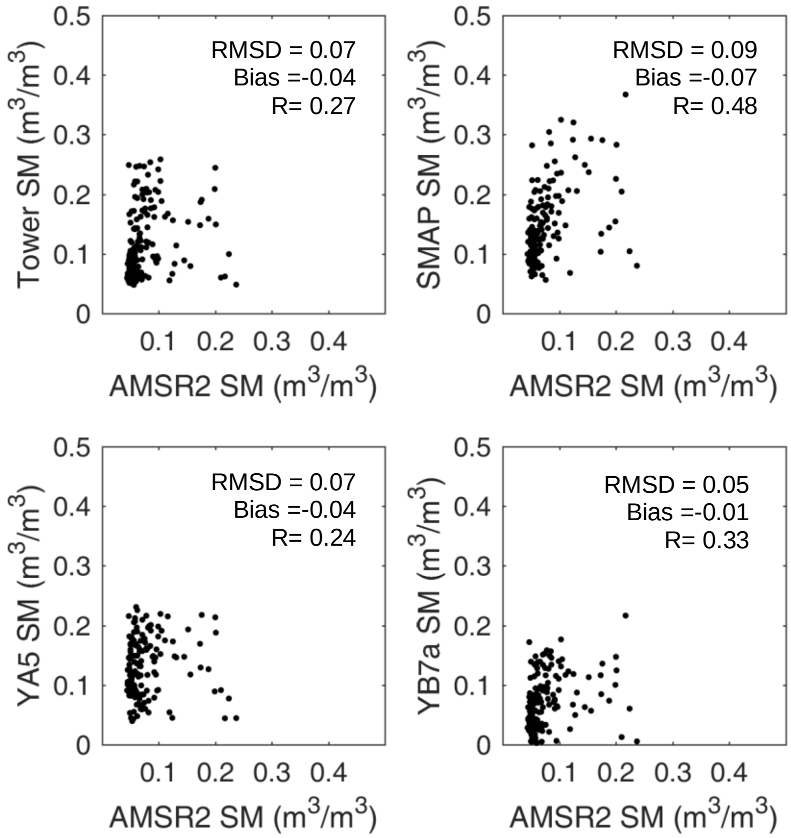


Figure 29: Scatter plots of AMSR2 SM (10-km) against soil moisture from the tower, SMAP observations, YA5 station and YB7a station.

In order to access the accuracy of the tower soil moisture measurements, tower soil moisture is also plotted against AMSR2 product, SMAP product and the two OzNet station measurement, respectively (Figure 30). Statistics are also calculated to quantify the accuracy. Results show the tower observations match better with the SMAP product with an accuracy of 0.06 $m^3/m^3$ and a very small 0.03 $m^3/m^3$ bias. Tower soil moisture also has a relatively good agreement with the two representative OzNet stations, with accuracy smaller than 0.06 $m^3/m^3$ and superior

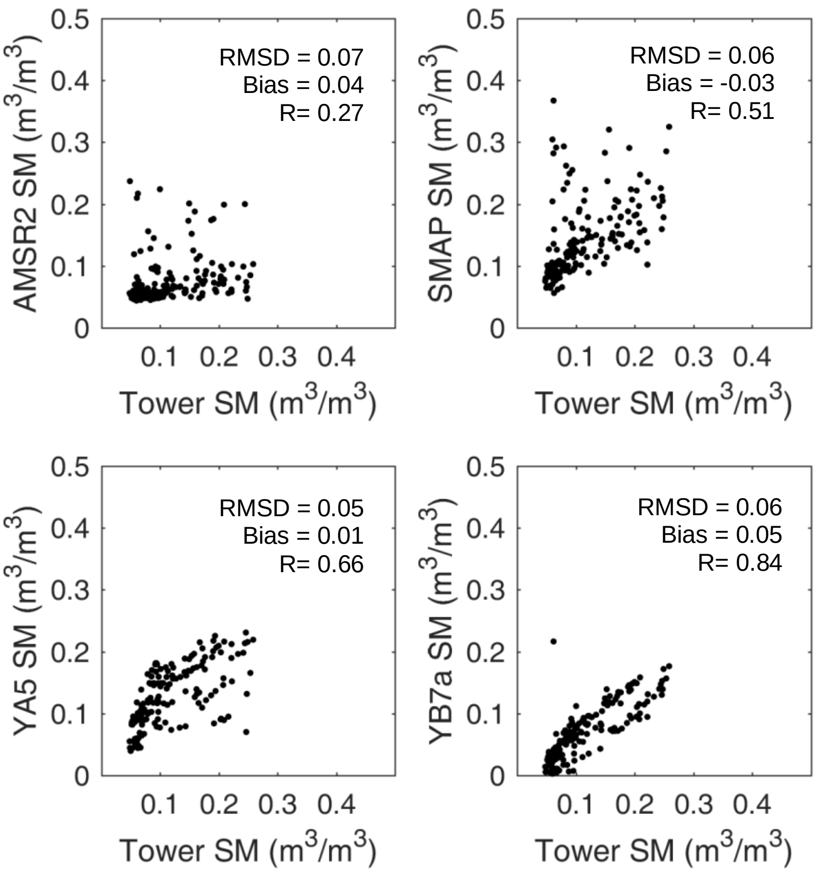


Figure 30: Scatter plots of tower soil moisture against AMSR2 SM (10-km), SMAP SM (36-km), YA5 and YB7a station soil moisture.

correlation of higher than 0.84 for YB7a. This means that tower measurements are closer to the soil moisture 'truth' and is reliable as a source of validation tool.

Figure 31 Compare AMSR2 SM against 3 in-situ stations from 2015-2016, 2017-2018 to 2018-2019. It is seen that as weather becomes drier, the dynamic of soil moisture range becomes smaller. As C-band retrieval has smaller dynamic range, the RMSE and bias become better as weather gets drier. However, the correlation is getting worse because the higher AMSR2 SM for wet season is very scattered during 2017-2018 and 2018-2019, therefore does not capture the increasing and decreasing trend as 2015-2016.

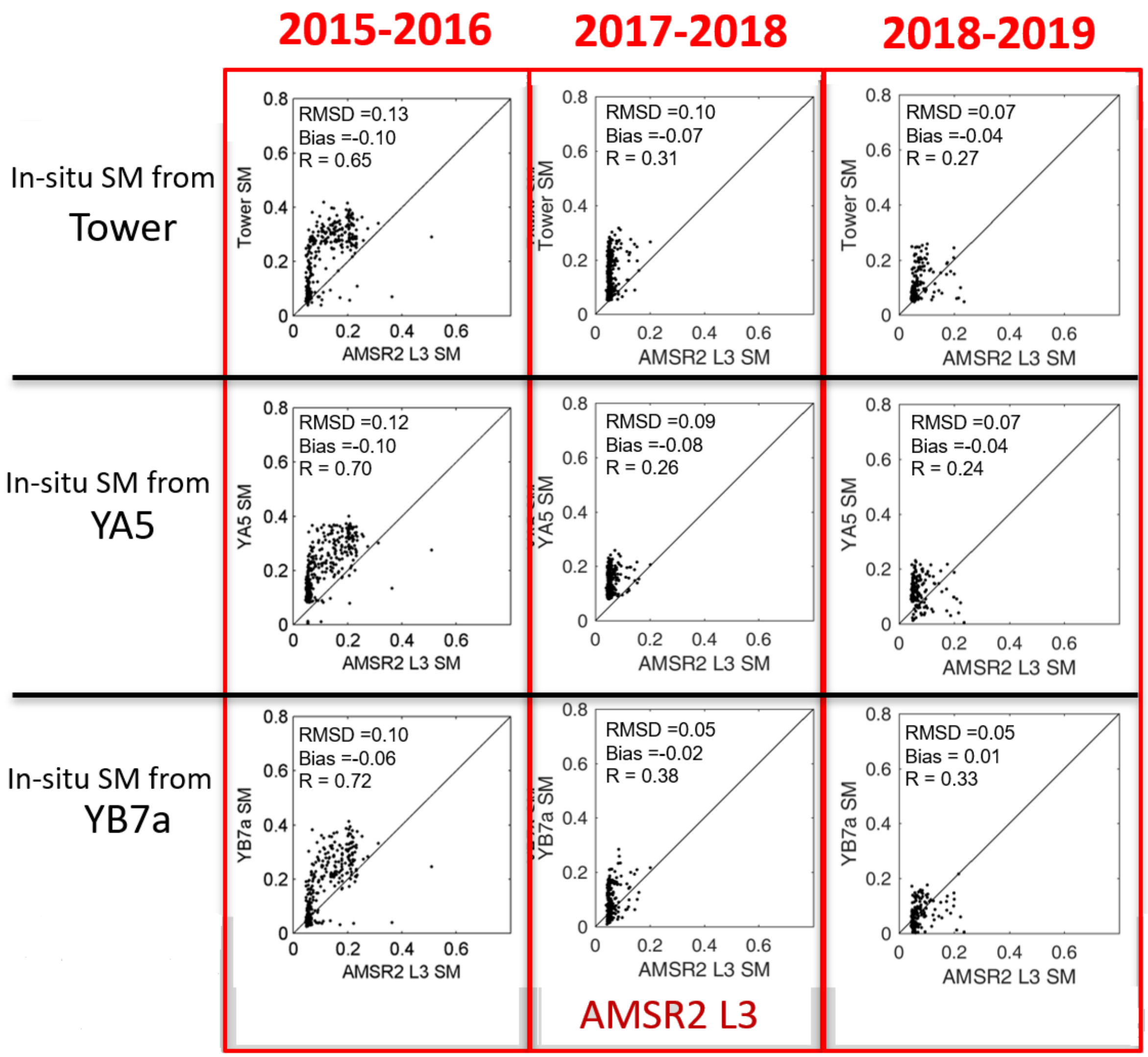


Figure 31: Comparison of AMSR2 L3 SM validation among 2015-2016, 2017-2018 and 2018-2019.

# Chapter 6: Validation of Land Surface Model Data Assimilation Against AMSR2 and Tower

## 6.1 The LSM Data Assimilation Methodology

Soil moisture from 2 assimilation experiments at the JAXA tower location are validated against tower data and compared with AMSR2 soil moisture product. Assimilated latent heat and sensible heat is also validated against tower data.

The assimilated data was provided by Clara Draper from University of Colorado. The methodology of the LSM data assimilation can be found in Draper and Reichle (2019). According the study presented in the article, the GEOS land EnKF was used to assimilate the soil moisture observations. This is a stochastic EnKF and was run in ‘1-D’ mode, in which all horizontal error correlations are neglected, using a 3-hr assimilation cycle and 20 ensemble members. Only a single realization of the land/atmosphere system is available from MERRA-2, and following standard practice in offline land DA, the ensemble of land states for the EnKF was created by randomly perturbing the atmospheric forcing and land state variables, using the same perturbation settings as in Liu et al. (2011). The model and assimilation were performed on the same approximately 0.5° grid, and the output was written on the same 0.5° by 0.625° latitude-longitude grid used for MERRA-2 output.

The soil moisture retrievals from both active and passive sensors have been assimilated, in this case from the C-band active ASCAT, and the L-band passive SMOS instruments, respectively. The assimilated ASCAT observations were version WARP5.6.5. The soil moisture observations are retrieved from the ASCAT instruments on the MetOp-A and MetOp-B satellites, and have a resolution of approximately 25 km, but are reported on an over-sampled 12.5 km Discrete Global Grid (DGG). The assimilated SMOS soil moisture retrievals were extracted from the SMUDP2 product v552, on a 15 km DGG grid. The ASCAT and SMOS observations were regridded onto the MERRA-2 output grid before being assimilated, by assigning the average of all observations that fall within each MERRA-2 grid cell to all land model tiles within that cell. More information on the methodology can be found in Draper and Reichle (2019).

In this study, both the LSM-DAland and LSM-openloop results are taken for validation against AMSR2 and tower. The DAland uses assimilated data from ASCAT and SMOS soil moisture product, while the openloop uses none of the data. The time period 2015-2016 of the assimilated results were applied here. A summary of the data used can be found in Table 1.

Table 1. Validated LSM data assimilation in this study

| | **Model** | **Assimilated Data** | **Time Compared** |
|---|---|---|---|
| **LSM-DAland** | Catchment LSM (driven with MERRA-2 surface meteorological data) at resolution of $0.5^0$ | ASCAT and SMOS soil moisture products | 2015-2016 |
| **LSM-openloop** | Catchment LSM (driven with MERRA-2 surface meteorological data) at resolution of $0.5^0$ | None | 2015-2016 |

## 6.2 The Validation Results

The timeseries of LSM assimilated soil moisture at ~50km pixel where JAXA tower is located were plotted together with the AMSR2 product and tower soil moisture, as shown in Figure 32 (1). Compared with the tower soil moisture, the LSM assimilated soil moisture tend to overestimate the lower values, while underestimate the higher ones. It successfully captured most of the peak values. Moreover, it correlates well with the AMSR2 soil moisture product as well.

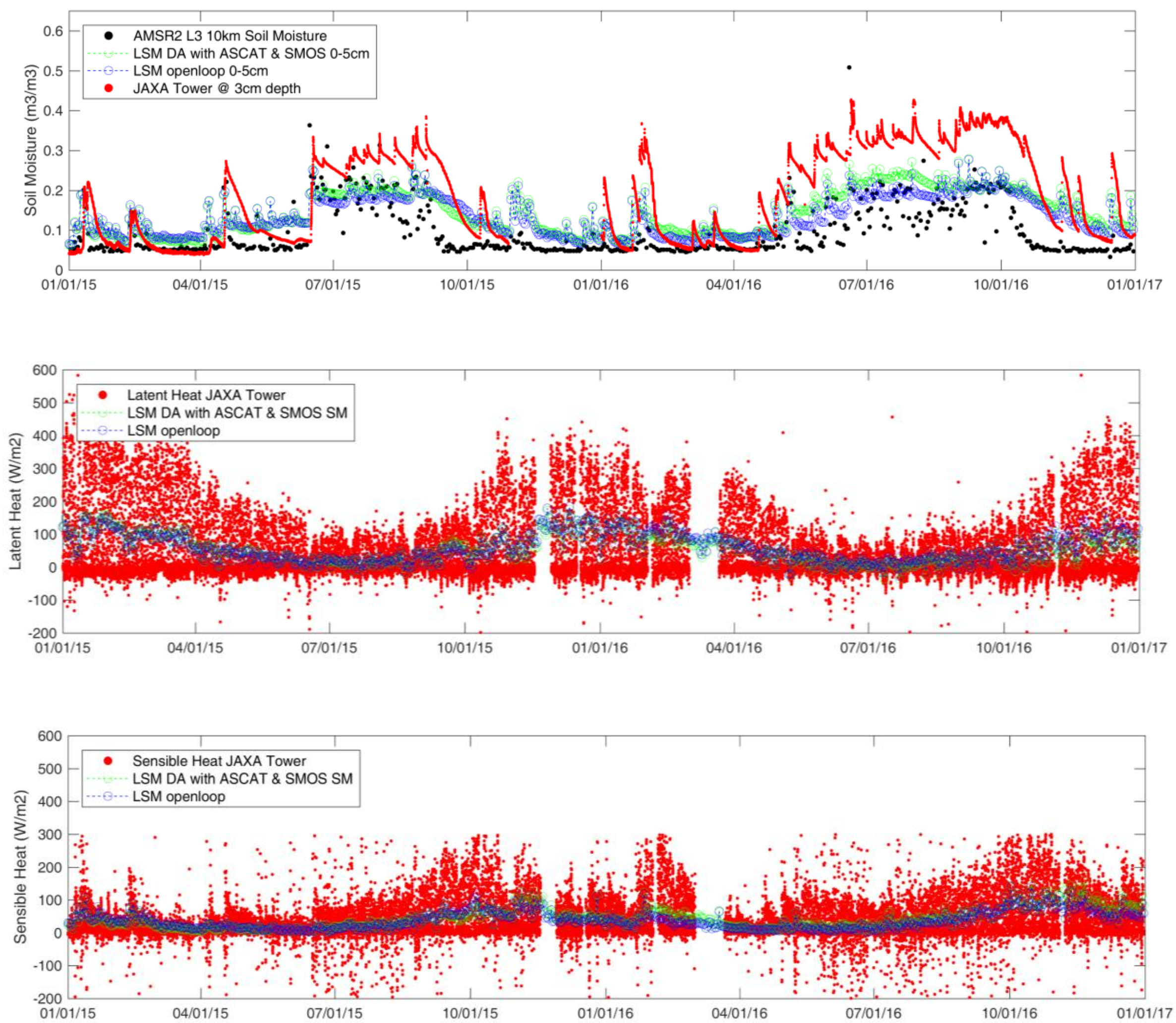


Figure 32: Validation of the LSM assimilated (1) soil moisture against AMSR2 and tower; (2) latent heat against tower; and (3) sensible heat against tower

Assimilated latent heat (LH) and sensible heat (SH) were also plotted against tower measurements of LH and SH, respectively. Despite the tower measurements have a higher sampling frequency (every 20 min), they both have a very good correlation with the assimilated LH and SH. In order to obtain a better comparison under the same time frequency, the tower data were averaged to daily values, as seen in

Figure 33 instead. It is seen that the daily data correlates with the assimilated data almost perfectly over the 2015-2016 period, despite the assimilation just slightly overestimates the 'truth'.

More LSM data covering 2017-2019 period is to be analyzed in the future.

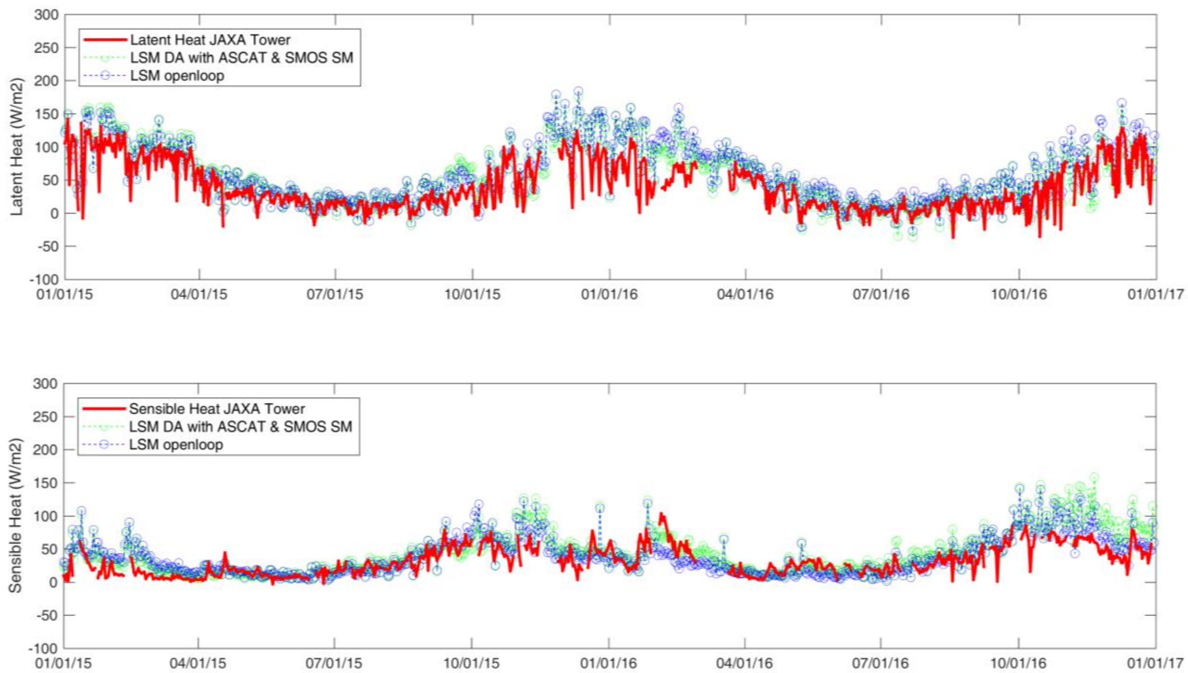


Figure 33: Validation of the LSM assimilated (1) latent heat against tower; and (2) sensible heat against tower, both with daily time stamp.

As shown in Figure 34, the scatter plots of the DA/openlood results against AMSR2 and tower showed similar story. The statistics show that RMSD of DA/openloop and AMSR2 product is only 0.06 $m^3/m^3$, which is quite accurate. The RMSD against tower is also relatively good, being 0.08-0.09 $m^3/m^3$. In terms of correlation, tower SM is slightly better than AMSR2.

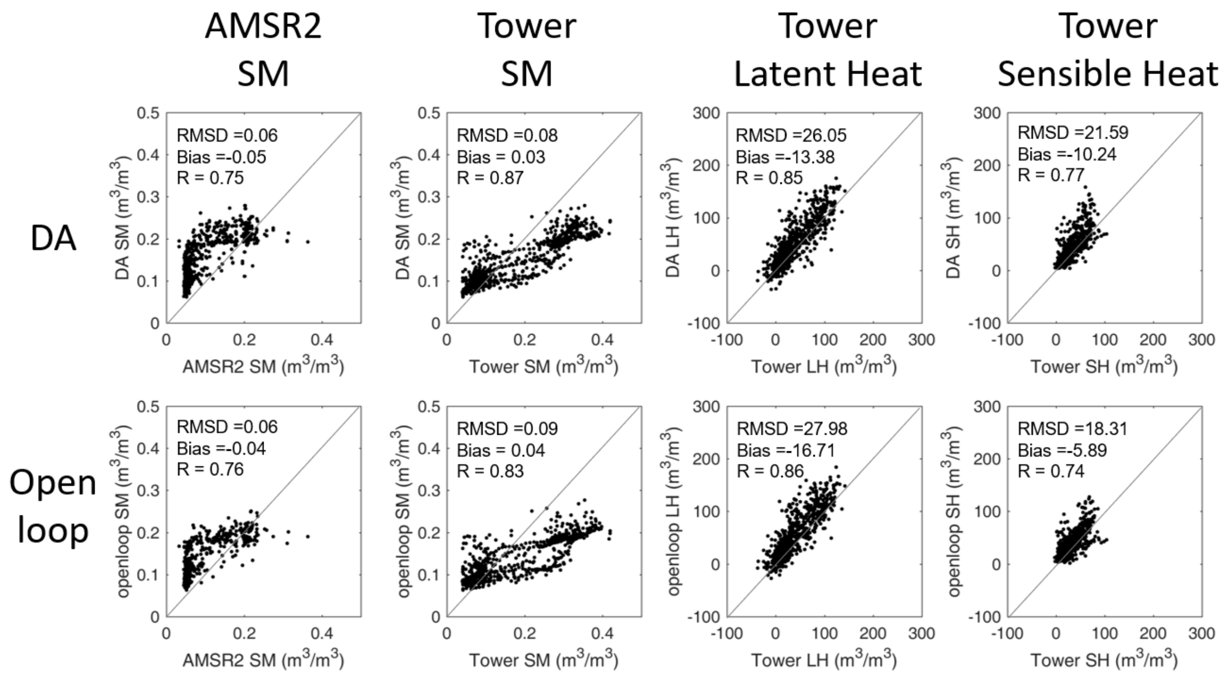


Figure 34: Scatter plots of the LSM assimilated SM against both AMSR2 and tower; and LH and SH against just tower, respectively.

# Chapter 7: Future Work

One of the major work that is currently underway is the estimation and validation of the crop coefficient/plant factor – Kc.

- Target - Validate satellite Kc against in-situ Kc.
- Why Kc - Crop coefficient (Kc) is crucial for estimating actual crop evapotranspiration (ETa) and planning appropriate irrigation management for efficient crop yield.

The proposed methodology includes two main aspects:

1. Calculation of Satellite Kc

- Kc is comprised with 2 parts: soil evaporation component (Ke) and vegetation transpiration component (Kcb).
- Ke can be estimated from AMSR2 SM product; Kcb can be estimated from MODIS vegetation indices (Park et al, 2017).

2. Calculation of in-situ Kc

- Kc = ETc / ETo. ETc is crop evapotranspiration; ETo is reference evapotranspiration. Both can be calculated from FAO Penman-Monteith equation, with flux tower data such as wind speed, air T, soil heat fluxes etc.

Another major work to be started is the validation of AMSR2 VWC research product (will commence once the research product is available from JAXA).

- Target - Validate the AMSR2 VWC research product at 10km resolution which is currently under development.

The proposed methodology includes two main aspects:

1. Validation of AMSR-2 VWC with calculated VWC from MODIS vegetation indices (e.g. from NDVI and NDWIs using equations from Gao et al, 2015)

2. Validation of AMSR-2 VWC with field sampling collected from SMAPEx-4 and SMAPEx-5 field campaigns at Yanco area.

# Chapter 8: Summary and Conclusion

This report presents the JFY 2019 research results for the project 'Validation of global water and energy balance monitoring in the Australian Murray-Darling Basin using GCOM-W1 data'. During JFY 2019, this project focused on: i) Continuing the validation of the AMSR2 soil moisture product against in-situ observations, ii) Intercomparing the AMSR2 soil moisture product with complimentary satellite soil moisture products from other missions, such as SMAP, and iii) validating the land surface model simulated soil moisture and flux data using AMSR2 products.

Similar to 2017-2018, results indicated that the AMSR2 L3 soil moisture product match with the JAXA tower and in-situ station measurements relatively well during the dry season (when soil moisture is smaller than 0.1 $m^3/m^3$). For 2018-2019, AMSR2 L3 product (10km & 25km) still underestimates the soil moisture when compared with the tower measurements and representative stations, especially during wet season (soil moisture ranges from 0.1-0.5 $m^3/m^3$).

Compared to 2015-2016 and 2017-2018, the AMSR2 soil moisture validation statistics in 2018-2019 perform better in terms of RMSE and bias, but worse in correlation. The land surface model assimilated soil moisture using ASCAT and SMOS has overall good agreement with the AMSR2 SM product, with an RMSD of 0.06 $m^3/m^3$; assimilated latent heat/sensible heat also match very well with tower data.

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# Validation of GCOM-W1 products using global water and energy balance monitoring at the Murray-Darling Basin in Australia

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