U.S. Climate Reference Network (USCRN) Program

Official Algorithm for Precipitation

Version 2.1

Description of Minor Change

March 8, 2016

Introduction

The USCRN Official Algorithm for Precipitation 2.0 (OAP 2.0) fundamentally changed the procedures used by the USCRN Program to calculate precipitation using three redundant measurements of depth from the Geonor weighing bucket gauge. The shift away from an existing pairwise testing approach, referred to as OAP 1.0, to a weighted average method based on each sensor's noise level, referred to as OAP 2.0, has greatly improved the network capacity to detect lighter precipitation with greater confidence as documented in Leeper et al. (2015). However, when precipitation was recalculated using OAP 2.0, several issues arose:

1) Recent revisions to the disdrometer (wetness sensor) range checks inadvertently were not incorporated, which allowed wetness observations that should have been flagged to be used in precipitation calculations;

2) Procedural changes (i.e., order of quality control checks, calculation steps, etc.) implemented in OAP 2.0 were found to result in unintended comparisons of newly calculated and previously calculated precipitation; these ingest processes were revised to use newly calculated precipitation exclusively and otherwise improve efficiency of data handling;

3) Finally, a minor correction was made to a portion of the new software to limit to 0.3 mm the carryover of small residuals of the current hour precipitation calculation. This has no impact under normal circumstances, but serves to limit the size of incorrect precipitation calculations that occur when a Geonor suffers a type of electronic failure that generates noise in multiple depth measurements simultaneously. These events are permanently removed by a manual exception procedure, but the software change limits the size of these events in real time precipitation calculations and prevents 5-minute precipitation values from exceeding established limits. The new version of the precipitation calculation software reflecting this upgrade is referred to as OAP 2.1.

An analysis has been conducted to compare calculated precipitation from all three OAP versions (1.0, 2.0, and 2.1) and ensure that recent changes reflected in OAP 2.1 and ingest software resolve the aforementioned issues. In addition, reprocessing times from OAP 2.0 and OAP 2.1 were compared to evaluate calculation efficiency gains from upgrades to the USCRN ingest software, and ensure precipitation exceptions are properly applied. Precipitation comparisons will focus solely on U.S. based USCRN stations from 2006 to 2014, which postdates the wetness sensor introduction.

Results

OAP Precipitation Comparisons

Total precipitation from the three OAP versions ranged from 871.5 to 900.0 thousand mm (Figure 1) with OAP 2.0 reporting slightly more precipitation than OAP 2.1. The precipitation difference between OAP versions 2.0 and 2.1 was less than 0.3%, with OAP 2.1 still reporting 2.9% more precipitation than OAP 1.0. This relationship was consistent in time (Figure 2). From 2006 to 2014, annual OAP 2.0 percent differences from OAP 2.1 ranged between 0.02 and 1.73% with the largest difference reported in 2011. Conversely, OAP 1.0 consistently reported less precipitation than OAP 2.1, from -1.46 to -6.10%. The larger differences during the earlier years may be partially explained by the greater level of sensor noise during this time, which site engineers learned to mitigate over time. Despite these differences, it was interesting to note that all three OAP versions had a rise in network total precipitation from 2006 to 2009 as more stations were added to the network and a slight drop in 2012 caused by the well documented drought in that year.

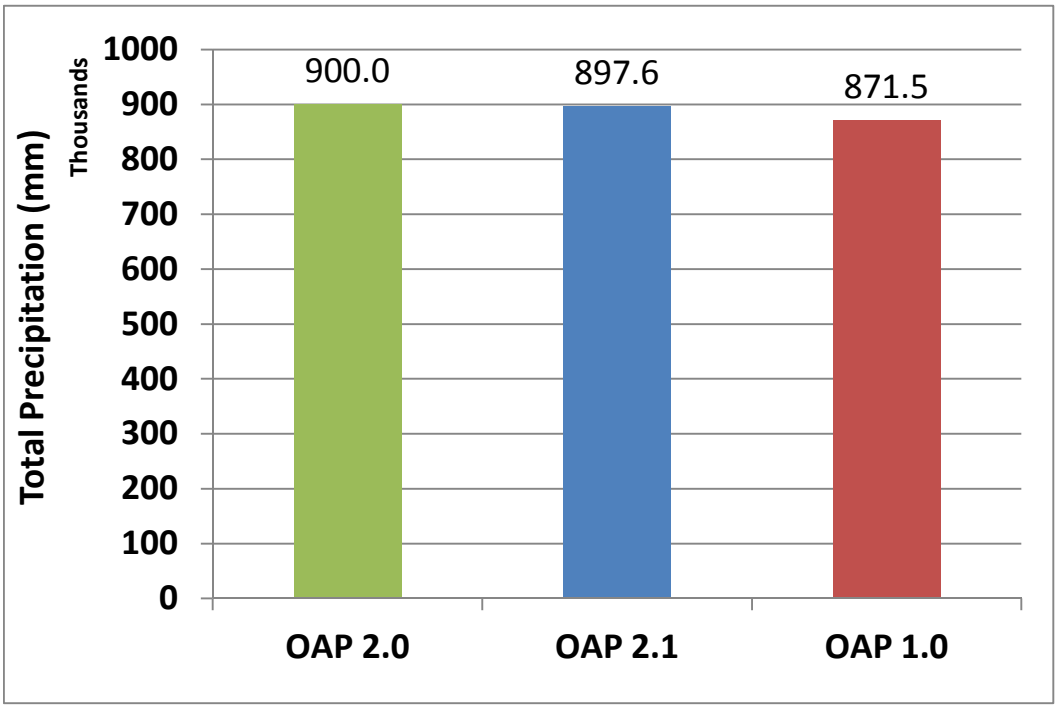

Figure 1. Total precipitation from all U.S. based USCRN stations calculated from OAP versions 1.0, 2.0 and 2.1.

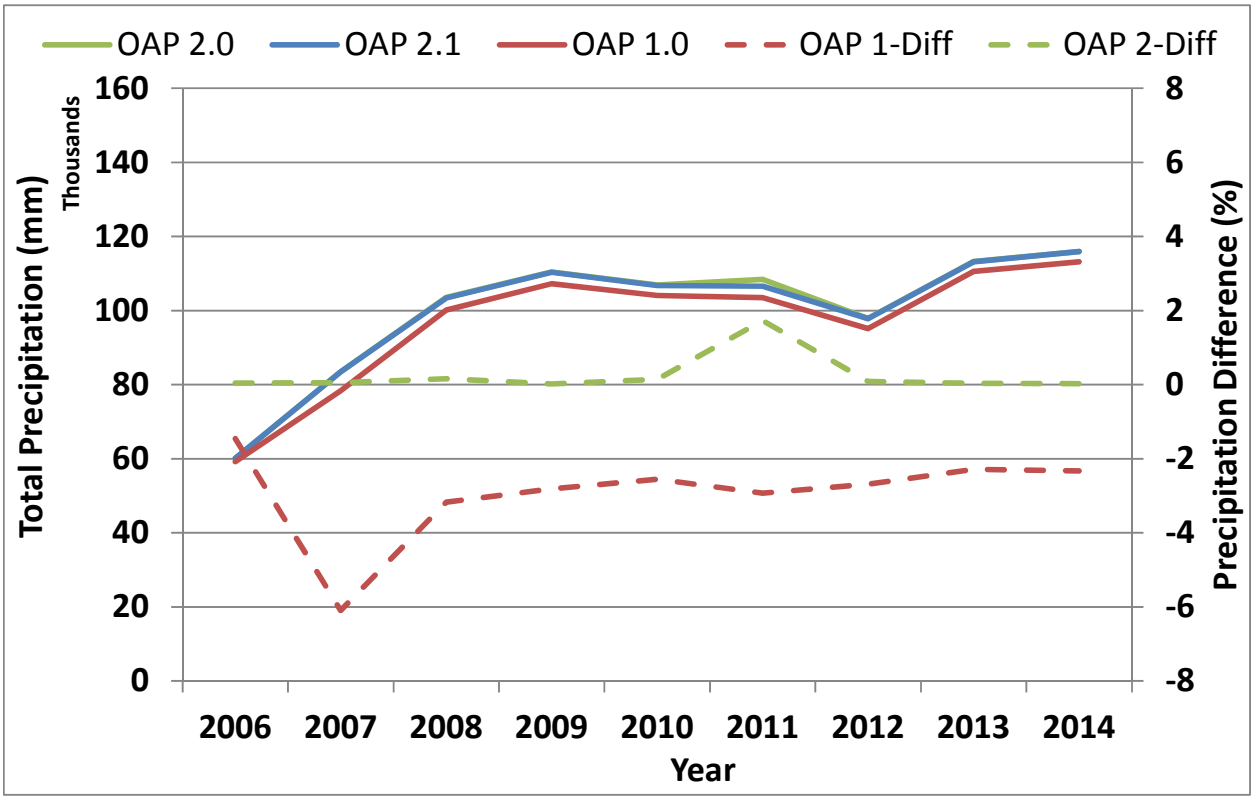

Figure 2. Annual total precipitation for all three OAP versions (solid lines) and percent differences (dashed lines) with respect to OAP 2.1 from all USCRN stations calculated using OAP 1.0 and 2.0.

Precipitation totals for individual stations were very similar among the three OAP versions (Figure 3); correlations with respect to OAP 2.1 exceeded 0.99 for both versions 1.0 and 2.0. The largest reported outlier occurred at Port Alsworth, AK, where OAP versions 2.0 and 2.1 reported 4680.9 and 2808.4 mm respectively. In fact, this single station explained 77.9% of the total network difference between OAP 2.0 and 2.1. Conversely, precipitation differences between OAP 1.0 and 2.1 were not driven by a single station, but instead by smaller station differences over a greater number of stations (Figure 4). For OAP 1.0, nearly half the network stations experienced less than 0.5% change despite having the greatest difference with respect to OAP 2.1. For instance, one must include the top 49 stations with the largest differences to explain 77.9% of OAP 1.0 differences.

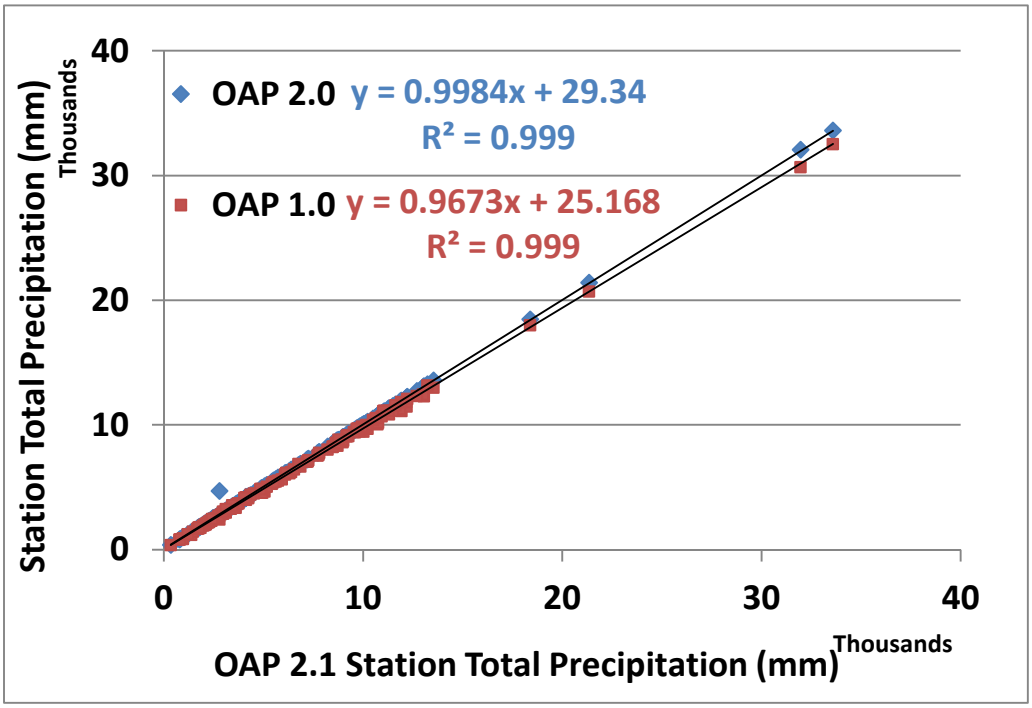

Figure 3. USCRN station total precipitation calculated using OAP 2.1 correlated with totals from OAP versions 1.0 (red) and 2.0 (blue).

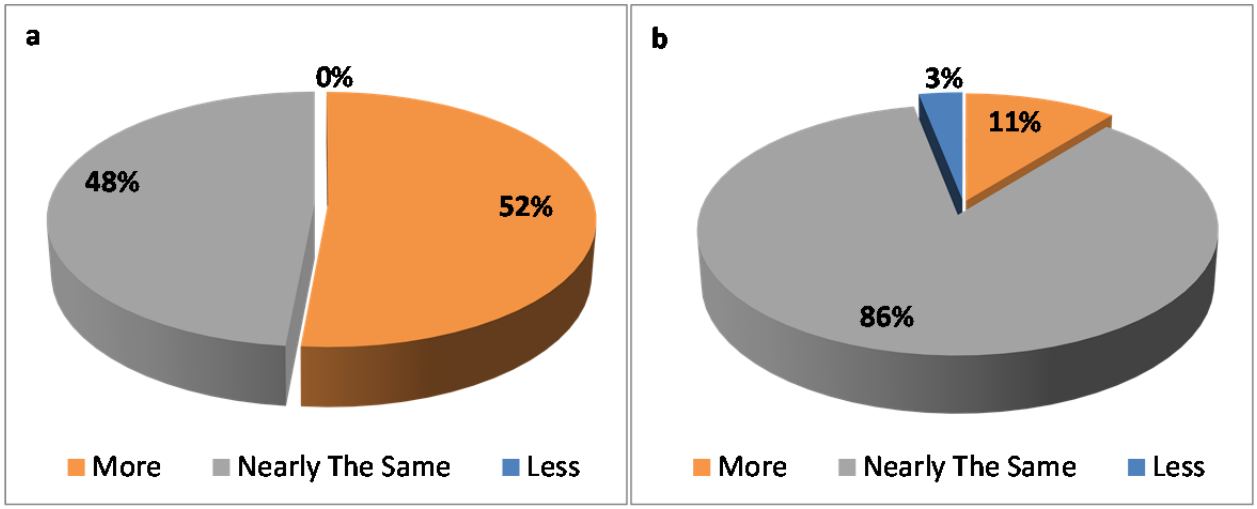

Figure 4. Percent of USCRN stations where precipitation totals calculated with OAP 2.1 are compared to (a) OAP 1.0 and (b) OAP 2.0. With respect to OAP 2.1, precipitation values are 0.5% more (orange), 0.5% less (blue), or nearly the same (gray) during the period 2006 to 2014.

Further investigation into the Port Alsworth, AK, station revealed that OAP differences at this station were primarily observed in April-May 2011 (Figure 5). Over May 2011 alone, OAP 2.0 calculated 1595.1 mm more precipitation than OAP 2.1, explaining the increase in 2011 network-wide percent differences shown in Figure 1. There were several instances in April and May of 2011 where electronic interference caused gauge observations at the Port Alsworth, AK, site to behave erratically, resulting in false precipitation during hours when sensor depths synchronously increased and wetness was falsely detected (Figure 6). These instances have been well documented and declared to be an exception pending approval by the USCRN configuration control board (CCB). Less precipitation was calculated by OAP 2.1 because wetness sensor observations were properly flagged and sub-hourly calculations complied with algorithm defined range checks. It is important to note that this test was performed without removing the exception event period so that the impact of this type of event in real time (prior to manual detection) could be gauged. OAP 2.1 clearly reduced the impact of errant sensors on calculated precipitation.

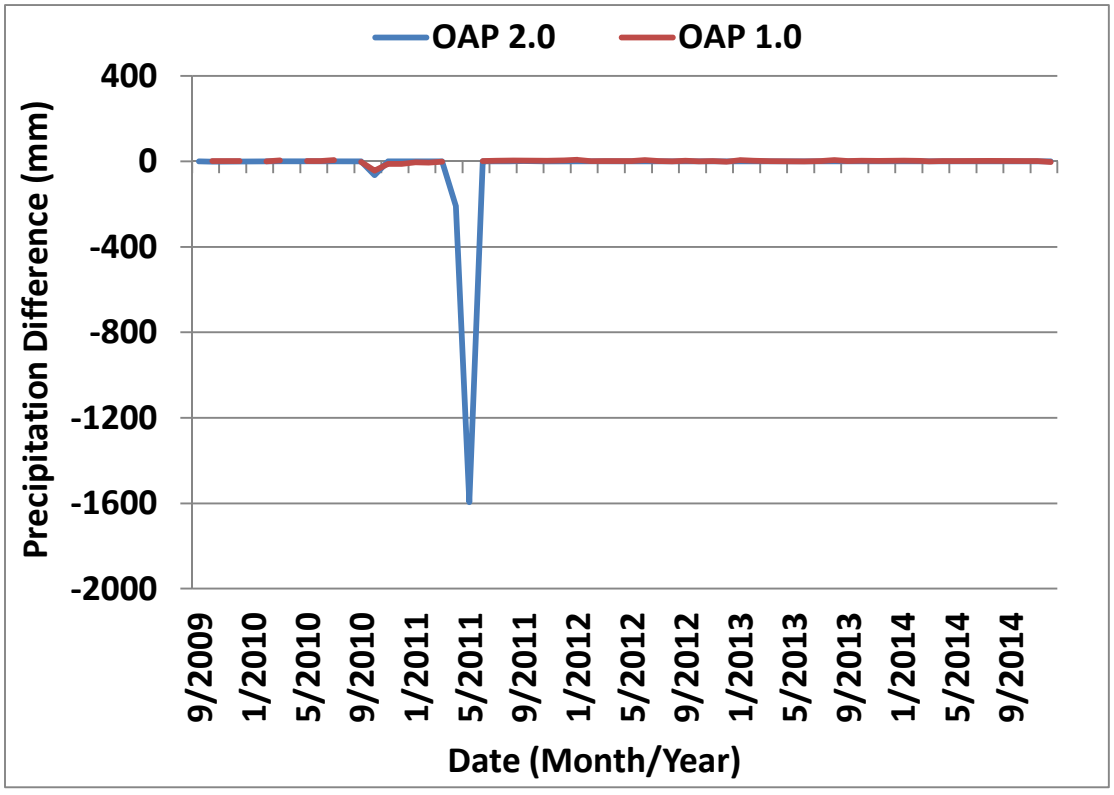

Figure 5. Port Alsworth, AK, monthly precipitation difference computed from OAP 2.1 for OAP versions 2.0 (blue) and 1.0 (red).

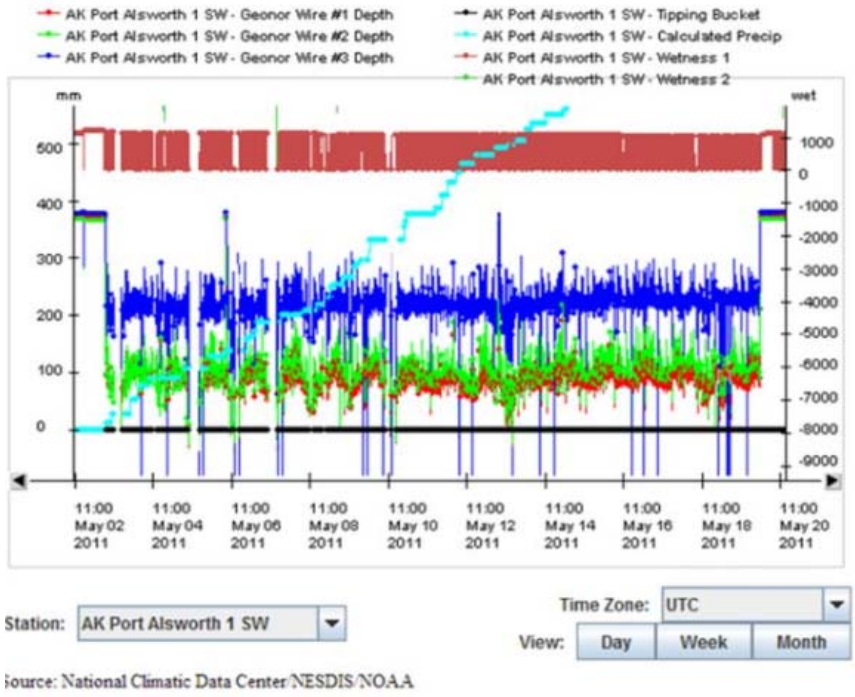

Figure 6. Port Alsworth, AK sensor observations from May 2nd to May 20th 2011 for Geonor gauge depths from wire 1 (red), wire 2 (light green), and wire 3 (dark blue), wetness sensor channel 1 resistance (light red), accumulated tipping bucket precipitation (black) and OAP 1.0 accumulated precipitation (light blue). Wetness sensor and all three depth records are later flagged as exceptions and weighing bucket "official" precipitation not calculated.

Reprocessing Time & Exceptions

Revisions to the ingest software also were made to significantly reduce reprocessing times. Based on estimates of time to process each station observation, the recalculation of precipitation from 2006 to 2014 would have taken approximately 234 days to complete. By removing redundancies in the ingest software, the recalculation of OAP 2.1 finished in 13 days or approximately 18 times sooner. This significant increase in efficiency for the recently revised ingest software applies not only to reprocessing of precipitation, but any future reprocessing efforts (i.e. soil moisture, air temperature, etc.).

In addition, an exception was successfully applied to the Port Alsworth, AK, station using the latest ingest software. For the periods in April and May when electronic interference impacted the quality of gauge observations, Port Alsworth, AK, observations were manually flagged using the exception process. After the exception was applied, OAP 2.1 precipitation calculated no precipitation during the exception period and gauge observations were flagged as expected.

Conclusion

These results indicate that software updates to both ingest and the official algorithm for precipitation resulted in slightly less calculated precipitation for OAP 2.1 (~ 0.3% less). However, the reduction in precipitation was primarily observed at a single station (Port Alsworth, AK) where known electrical interference resulted in false precipitation. These minor software adjustments improved OAP 2.1 handling of erratic gauge behavior due to the proper flagging of wetness sensor observations and ensuring precipitation calculations comply with sub-hourly range checks by limiting residual carryover from one hour to the next to 0.3 mm. Despite the false precipitation at Port Alworth, AK, in 2011, OAP 2.1 retained all of the advantages of the major revision OAP 2.0 over OAP 1.0. Moreover, differences between OAP 2.0 and OAP 1.0 as reported in Leeper et al. (2015) and in the series of reports made for the operational readiness review of OAP 2.0 are negligibly impacted by the software updates reflected in OAP 2.1. In addition to improved handling of erroneous gauge data, software updates have significantly improved reprocessing efficiency. Finally, exception handling can be applied to gauge data and has been successfully implemented at the Port Alsworth, AK, station.