Preliminary look at MARCUS Tilt Corrected Broadband Radiation Data

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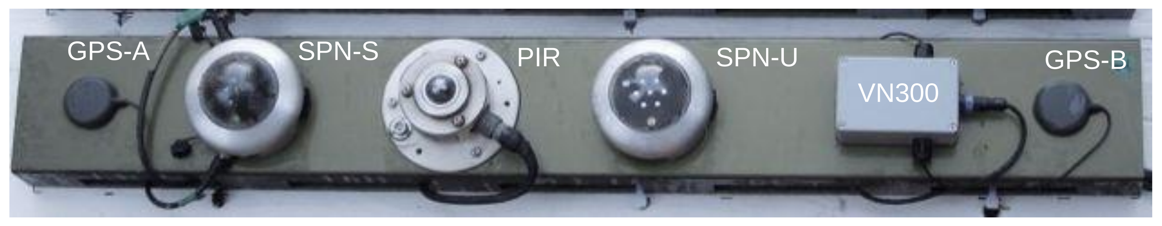
Moving Platform Radiometry

➢ Tilt from horizontal on moving platforms can result in substantial downwelling shortwave (SW) and longwave (LW) errors

➢ ARM has developed ship-board radiation packages (ShipRad) similar to that designed for the ARM Aerial Facility G-1 aircraft

➢ The ShipRad set of instruments provides all the information that is needed to apply the correction for tilt from horizontal orientation developed by Long et al. (2010) to the downwelling SW measurements, as well as screen the longwave measurements for data likely contaminated by too large tilt.

➢ Three ShipRad systems were assembled affording one each on the starboard and port sides of the ship, and one spare system in case of failures.



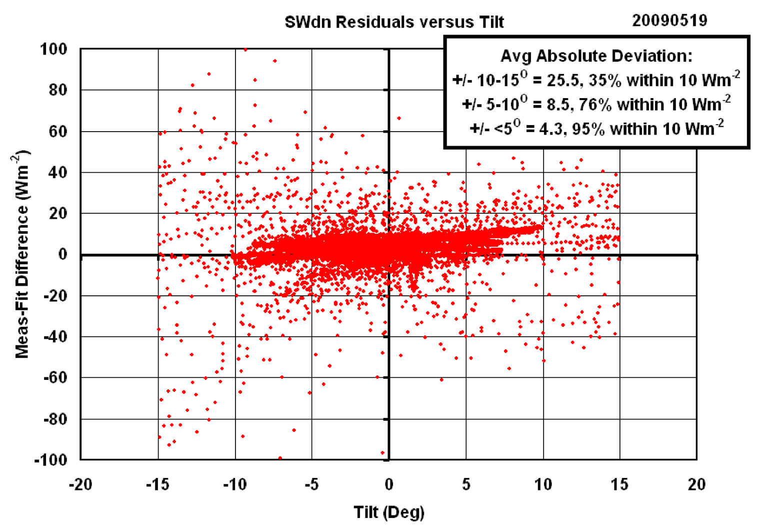
➢The Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS) campaign is the maiden deployment of the ShipRad systems.

Correcting Tilt from Horizontal

For modest tilt, only the direct part of downwelling SW should be corrected for tilt. Thus a-priori knowledge of the direct and diffuse partitioning is required along with navigation latitude, longitude, pitch, roll, and heading. Given these parameters, and the assumption that the tilted diffuse is nominally equal to the horizontal diffuse, the Long et al. (2010) technique is applied.

$$G = G_T \left(\frac{\mu_0 + D/N}{\mu_T + D_T/N} \right)$$

Equation for calculating horizontal SW (G) from tilted SW (G_T). N is direct normal SW, D is diffuse SW (assumed to be equal for modest tilt), μ_0 is the solar zenith angle, and μ_T is the tilt zenith angle = *f*(pitch, roll, heading)



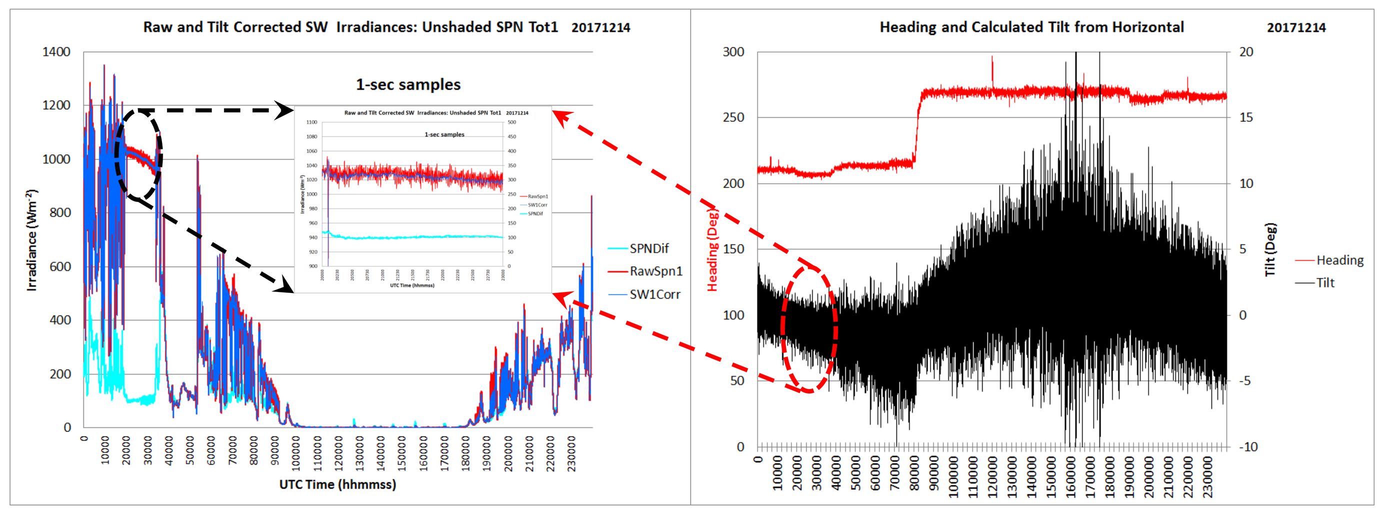
Long et al. (2010) show that the tilt correction methodology corrected 90% of the data to within 10 Wm^{-2} for tilt of +/- 10° or less, with an average absolute deviation of 5.2 Wm^{-2}, and 95% if the data within 10 Wm^{-2} for tilt of +/- 5° or less.

Long, C. N., A. Bucholtz, H. Jonsson, B. Schmid, A. Vogelmann, and J. Wood (2010): A Method of Correcting for Tilt from Horizontal in Downwelling SW Measurements on Moving Platforms, TOASJ, 4, pp.78-87, doi: 10.2174/1874282301004010078.

MARCUS Data

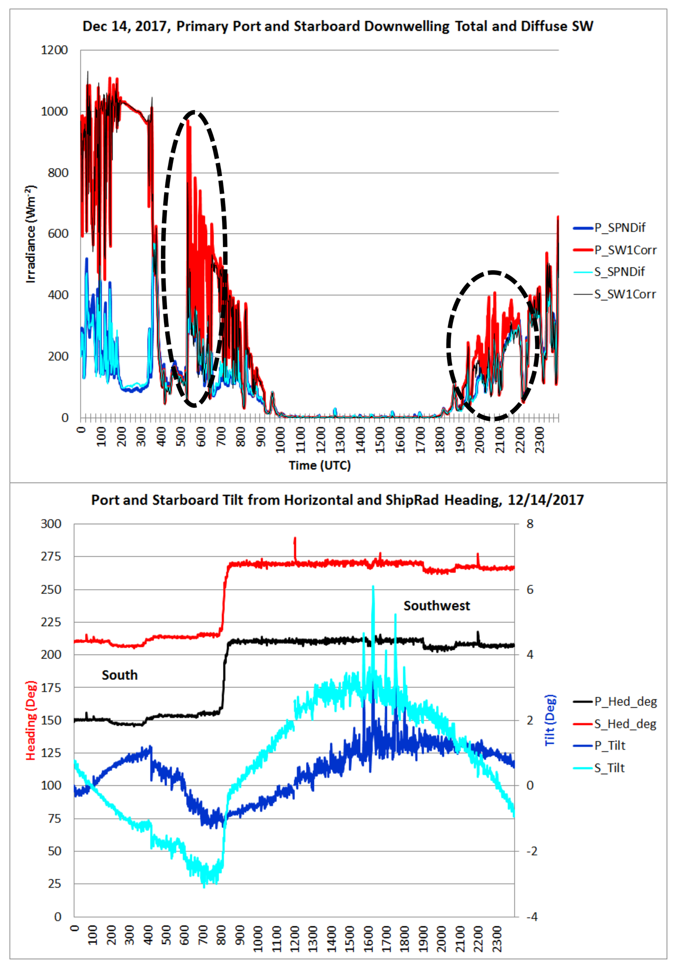
The campaign and data collection is still ongoing. These examples are from the first legs.

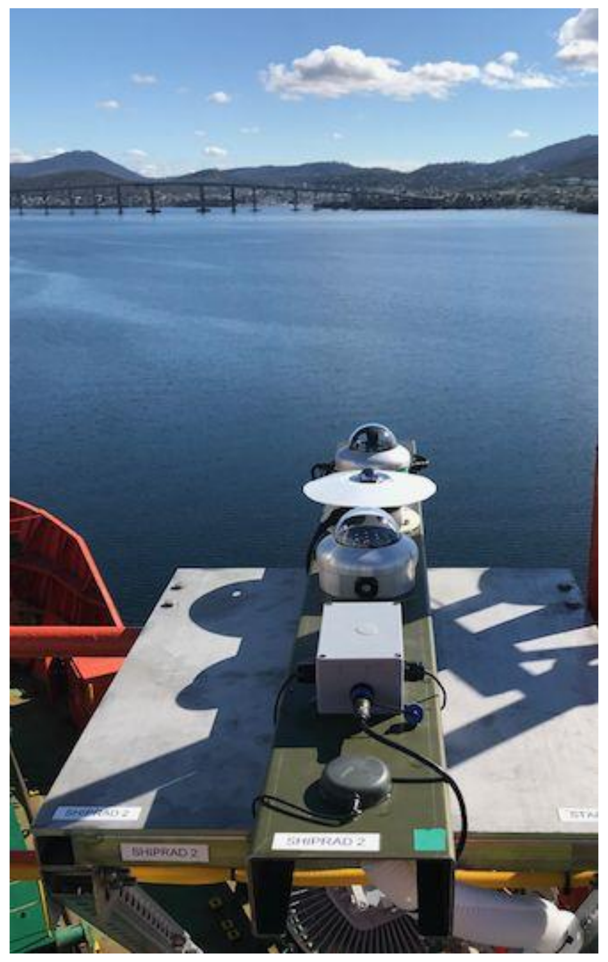
Example of tilt correction, Dec. 14, 2017:



A brief nearly clear-sky period (dashed circle) shows the effectiveness of the preliminary tilt correction. As the zoom plot shows, even without refined detector angular offset from nav correction, the noise in the 1-second samples is decreased from a spread of 30-40 Wm^{-2} to only a few Wm^{-2}. This despite the rapidly changing tilt from horizontal (black) shown in the right hand plot.

Usefulness of port and starboard systems:





Ship-board hemispheric measurements often suffer from shading by ship structure or due to the crowding of instruments, as in the example photo above showing shadowing of the primary SW radiometer in the middle of the system. To help mitigate interference with the downwelling irradiance measurements, one ShipRad system is deployed on each side of the ship. As in the example above (top plot, dashed circles), the starboard total SW is equal to its diffuse SW, and much less than the port side total SW. This suggests that the starboard radiometer was shaded by some obstruction and in this instance the port side SW is likely the better measurement.

The lower left plot shows the port and starboard ShipRad heading (left axis, red and black lines) and amount of tilt (right axis, blue lines) from 1-minute average data. The ShipRad systems are mounted on railings that are slanted with respect to the ship's keel. Thus the port ShipRad is offset by about a negative 30 degrees from ship heading, and the starboard ShipRad heading is about positive 30 degrees with respect to ship heading. These heading offsets then affect the amount of tilt differently for each system. The ship was headed south for the first part of this UTC day, then turned to the south/south west.

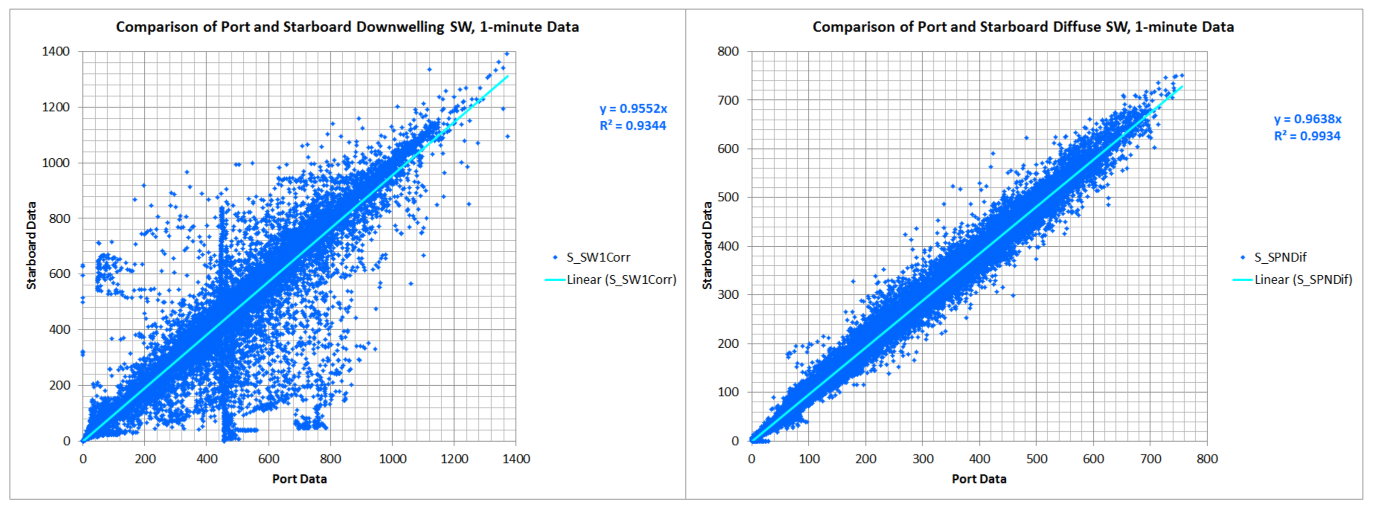
Summary

Making accurate downwelling shortwave irradiance measurements on moving platforms such as ships and aircraft requires correction of the data for tilt from horizontal orientation. ARM has developed ship-board radiation systems (ShipRad) similar to the radiation package developed for the AAF G-1 aircraft.

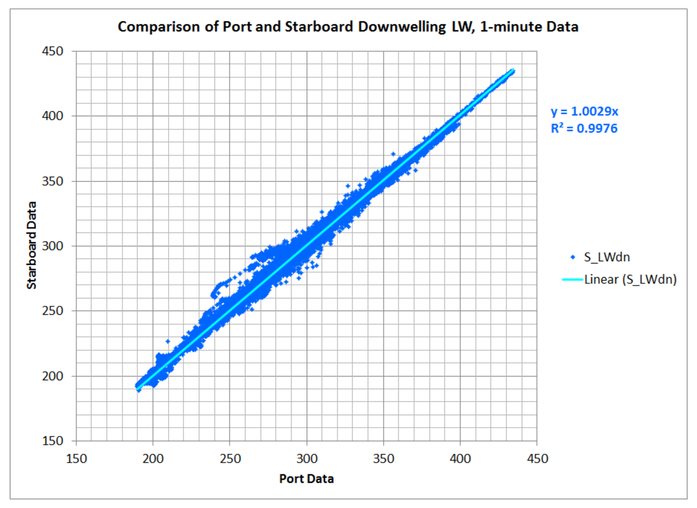
The maiden deployment of the ShipRad systems is for the MARCUS campaign with both a port and a starboard system to help mitigate shading by the ship structure and other close-by obstructions.

Preliminary data indicate the systems are functioning reasonably well after a few initial hiccups, and will provide more accurate, tilt corrected data for use in developing a "best estimate" radiation product for ship campaigns.

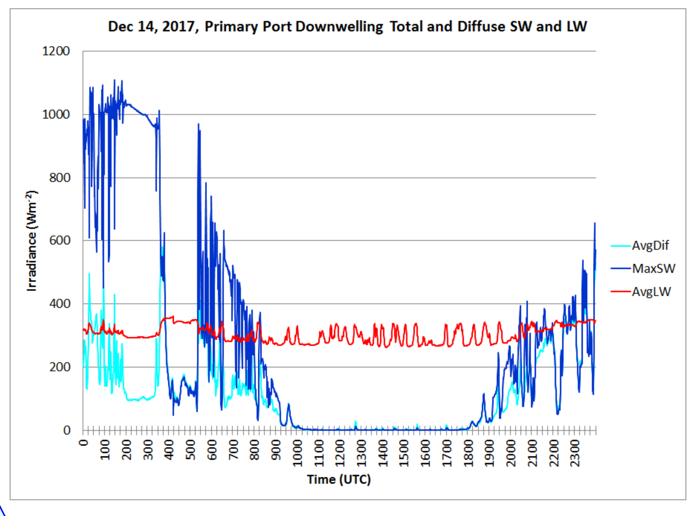
ShipRad Intercomparison



Large disagreements between port and starboard downwelling SW (left plot) are due to shading of one of the systems. The diffuse SW (right plot) does not show similar disagreements because the diffuse is already a shaded measurement.



Similar to the diffuse, the downwelling LW (left) is also effectively shaded from the sun by the radiometer's dome filtering.



Given all the above, one possibility for screening which side data to use as the "best estimate SW" might be to look for times when one side has diffuse about equal to the total SW but the other side shows the total SW significantly greater than the diffuse, and choosing the larger of the two total SW values. Using this screening, and averaging the two diffuse SW and the two LW measurements, produces the "best estimate" irradiances for the Dec. 14 case (left).