# Improved Accuracy in Shipborne Broadband Irradiance Measurements during MARCUS using New Tilt-Corrected SHIPRAD Systems

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**Abstract**

Surface broadband shortwave and longwave irradiance are key components of the surface energy budget and give insight on atmospheric constituents like clouds and aerosols as well as provide useful information for model evaluation. Surface irradiance measurements are particularly difficult to make over the ocean where few measurement platforms exist, and where the motion of ships and buoys makes the accuracy of the measurements challenging. During the US DOE ARM Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS) field campaign, new shipborne broadband radiation systems (SHIPRAD) were deployed for the first time to test correction. The systems include pyrgeometer measurements for measuring longwave irradiance, an unshaded pyranometer to measure shortwave irradiance, a navigation system measuring pitch/roll/heading, and an SPN1 shortwave radiometer that measures direct and diffuse components with no moving parts. A tilt correction methodology was used to correct 1 second temporal resolution shortwave irradiance data for ship motion, designed to correct tilts of 10 degrees or less to within 10 W/m2. Two SHIPRAD systems were deployed on the port and starboard sides of the ship, and the measurements were combined in order to be able to eliminate measurements shaded by ship structures. The new methodology allows for high-temporal resolution irradiance measurements with higher accuracy. Results will be presented on the accuracy of the tilt correction methodology and the irradiance measurement results throughout the campaign.

# A11J-2895: Improved Accuracy in Shipborne Broadband Irradiance Measurements during MARCUS using New Tilt-Corrected SHIPRAD Systems

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## SUMMARY

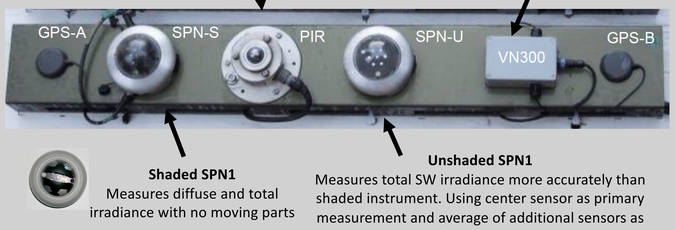
SHIPRAD Systems were developed to correct for measurement challenges of broadband irradiance on moving platforms. The instruments were first deployed during the MARCUS field campaign. These systems and data processing methodology corrects for:

1. Tilt from horizontal on moving platforms
2. Shading due to ship structures

*Planned data products will be produced with 1-minute average best estimate data. Collaboration and feedback on accuracy and resolution requirements happily accepted.*


## Instrumentation: SHIPRAD SYSTEM

***New ShipRad systems were designed to measure LW and SW broadband irradiance on ships. Deployed for the first time at the MARCUS field campaign, measurements of components of SW irradiance along with tilt and heading, allows for post processing to correct for tilt.***




## Offset Characterization

*Systems are characterized for offset from level compared to the VN300 to an accuracy of 0.1° to give the most accurate tilt correction possible.*

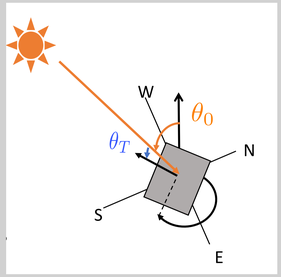
## Tilt Correction Methodology

***Direct SW Irradiance component is corrected for tilt up to 10° due to ship motion.***

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

Equation for calculating horizontal SW (G) from tilted SW (GT). Tilted Diffuse is assumed to be equal to Diffuse for small tilt angles, the cosine of the tilt zenith angle ($\mu_T$) is calculated as a function of pitch, roll, and heading.

### Definition of terms




Cosine of solar zenith angle:

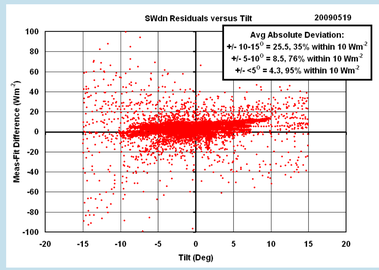
$$\mu_0 = cos(\theta_0)$$

Cosine of tilt zenith angle:

$$\mu_T = cos(\theta_T)$$

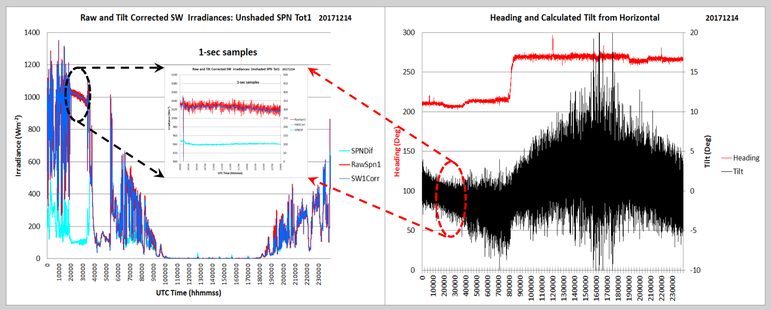
$G$: Total SW irradiance
$D$: Diffuse SW irradiance
$N$: Direct normal irradiance
$G_T$: Total SW on tilted surf
$D_T$: Diffuse SW on tilted surf

### Tilt correction for 10° or less within 10 W m$^{-2}$




Long et al. (2010) show that the tilt correction methodology corrected 90% of the data to within 10 Wm$^{-2}$ for tilt of +/- 10$^{O}$ 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$^{O}$ or less.

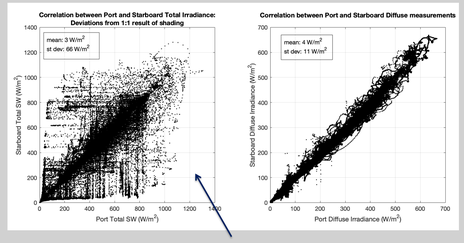
### Example of tilt correction, Dec. 14, 2017:




Methodology from Long et al. (2010). *TOASJ*, 4, pp.78-87, doi: 10.2174/1874282301004010078.

## Removing Shading Due to Ship Structures

- ***Two ShipRad systems are placed on port and starboard***
- ***Post Processing allows choice of unshaded measurements most of the time***




Comparison between port and starboard Total SW measurements shows large deviations due to shading that is not seen in diffuse SW irradiance

### Methodology for creating best estimate irradiance to avoid shading:

Downwelling LW and Diffuse SW: average of port and starboard measurements when tilt angle < 10°

Total SW—use average of port and starboard unless shaded:

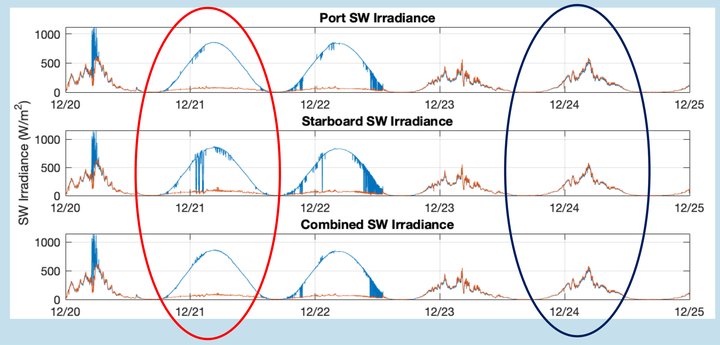
- When port/starboard total SW is >100 W m$^{-2}$ than starboard/port total
- When 1-sec deviation greater than 5 W m$^{-2}$




### Example combined

Combined data chooses times least impacted by shading when clear

Shading not a problem when cloudy

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