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Marine ARM GPCI Investigation of Clouds Sunshine Pyranometer (SPN1) Field Campaign Report

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CLIMATE RESEARCH FACILITY

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Acronyms and Abbreviations

AAF	ARM Aerial Facility
ARM	Atmospheric Radiation Measurement Climate Research Facility
CIRES	Cooperative Institute for Research in the Environmental Sciences (University of Colorado)
CLOWD	Clouds with Low Optical Water Depths
DOE	U.S. Department of Energy
ECO	engineering change order
ESRL	Earth System Research Laboratory (NOAA)
GEWEX	Global Energy and Water Experiment
GPCI	GEWEX Pacific Cross-Section Intercomparison
LW	longwave
MAGIC	Marine ARM GPCI Investigation of Clouds
nm	nanometer
NOAA	National Oceanic and Atmospheric Administration
PRP	Portable Radiation Package
RACORO	Routine AAF CLOWD Optical Radiative Observations
RSR	rotating shadowband radiometer
SPN	sunshine pyranometer
SW	shortwave
TCIP	Transit Communications Interface Profiles
WMO	World Meteorological Organization

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1.0 Summary

From the SPN1 manual, the SPN1 Sunshine Pyranometer is one sensor with three output channels: 1) total (global) solar radiation, 2) diffuse radiation, and 3) sunshine status. The SPN1 measures short-wave radiation between 400nm and 2700nm in W.m-2. The Direct beam component of solar radiation can be calculated from the Total minus the Diffuse component. The Sunshine status output indicates whether the energy in the direct beam exceeds the World Meteorological Organization (WMO) standard threshold value of 120 W.m-2, using an algorithm based on the Total radiation, and the ratio of Total to Diffuse radiation. The radiation outputs have a cosine-corrected response.

The advantages of the SPN1 are 1) It matches the WMO 'Good Quality' pyranometer classification. 2) It requires no shadow band or solar tracker. 3) There are no moving parts. 4) It does not need to be adjusted or repositioned to track the sun—a distinct advantage over shade rings or mechanical trackers. 5) It does not need to be oriented towards north. It will work accurately in any orientation as long as it is mounted horizontally. 6) It does not require knowledge of the latitude or longitude, and can be used at any latitude or longitude. 7) It measures sunshine hours as well as Total and Diffuse radiation. 8) The built-in heater allows use in wet or icy conditions.

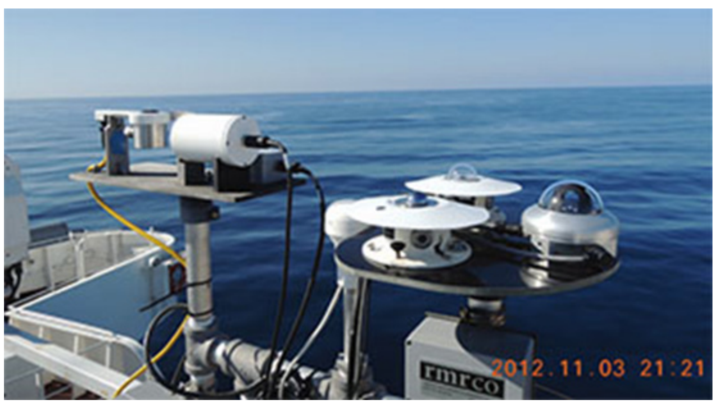

Figure 1. The Portable Radiation Package deployed during the MAGIC field campaign with the SPN1 on the right side.

Dr. C.N. Long has been looking into the SPN1 as an instrument that could be of use for the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility's second ARM Mobile Facility (AMF2), especially during at-sea times. On moving platforms such as ships and aircraft, most often the measured radiation is taken when the radiometer is not horizontal, but rather subject to being tilted from the horizontal, adversely affecting the desired horizontally oriented measurement. The SPN1 has been successfully used to correct downwelling broadband shortwave measurements for tilt from horizontal in a technique developed during the Routine AAF CLOWD Optical Radiative Observations (RACORO) aircraft campaign (Long et al., 2010). An SPN1 was added to the standard PRP during the MAGIC deployment to evaluate both how well the tilt correction technique might work for ship deployments, and what the magnitude of ship movements had on the downwelling shortwave measurements themselves.

2.0 Results

The standard Portable Radiation Package (PRP) includes delivering 1-minute averages from 1-second samples of the downwelling broadband shortwave (SW) and longwave (LW) irradiances. Both 1-sec raw and 1-min average samples were recorded. However, the averages of the raw data include whatever mean tilt the ship has during the minute, plus the assumption that the ship "rocking" around the mean tilt cancels out in the one-minute averaging process even though it is a non-linear process. It is not well quantified what effects this latter assumption, nor the mean tilt itself, has on the bias and uncertainties of the ship-based 1-minute averages. Thus it was decided to investigate by adapting the SPN1-based correction for tilt from horizontal methodology of Long et al. (2010) during the MAGIC cruise.

The data needed for evaluation of the SPN for tilt corrections were the 1-second samples of the radiometer data (these samples are what go into the standard 1-minute averages) as well as coordinated navigation data (pitch, roll, heading, latitude, longitude). Unfortunately when working with that data in order to determine the angular offsets between the radiometers and what the navigation system reported (see Long et al., 2010 for details), an issue was discovered with the time matching between the navigating system information and the radiometer data time stamp. Since the periodicity of the ship rocking during MAGIC was on the order of 10 seconds, we had a few seconds disparity between when the navigating system data were sampled associated in the data files with when the radiometer data were sampled (but both being assigned the same time stamp). An example is shown in Figure 2, where in this case the peak in the yellow oval of the navigation information (black) is time stamped 1:25:08. The peak in the uncorrected SPN1 Total SW (brown) is time stamped 1:25:09, and for the uncorrected PSP SW (red) is time stamped 1:25:10. This 2-second offset is 20% of the typical ship rocking cycle, making the data unusable for the tilt correction methodology, and in fact would likely make the data worse if applied as a tilt correction.

After significant effort to identify the issue, investigate the cause, and determine the magnitude of the temporal displacement, we discovered that the timing offsets occur at random when they do occur. The cause was tracked down to the fact that the system used the ship's available navigation data, and the data logging "called" for the ship data every second via Transit Communications Interface Profiles (TCIP) through the onboard internet system. However, the "get the navigation info" task was not assigned a high priority, so when the TCIP got busy, the calls for navigation information got "stacked up" in the queue, and then when higher-priority tasks were done, the queued-up navigation calls would be sent all at once, sometimes several seconds later. This navigation data would then be assigned a time stamp when they were received, rather than when they were generated. This issue is mentioned in the discussion of ARM Engineering Change Order ECO-00876.

As a consequence, identifying and correcting the timing offsets in the Magic 1-second samples data is a herculean and likely impossible task. Thus no further efforts will be expended on analyses or tilt correction application. However, this all has served as a "lesson learned" in that the utterly critical nature of having time synchronization between the radiometer and navigation data at the sub-second level has been loudly identified! Thus this effort has resulted in the re-design of the PRP idea into the "ShipRad" system based on the ARM Arial Facility aircraft radiation package design. This includes its own navigation unit as part of the radiometer system and logged by the same data logger as the radiometer data so it is time-synchronized, plus a separate part that includes the fast-rotating shadowband radiometer (RSR) and its own data logging and processing as before. See ENG0001169 for more details.

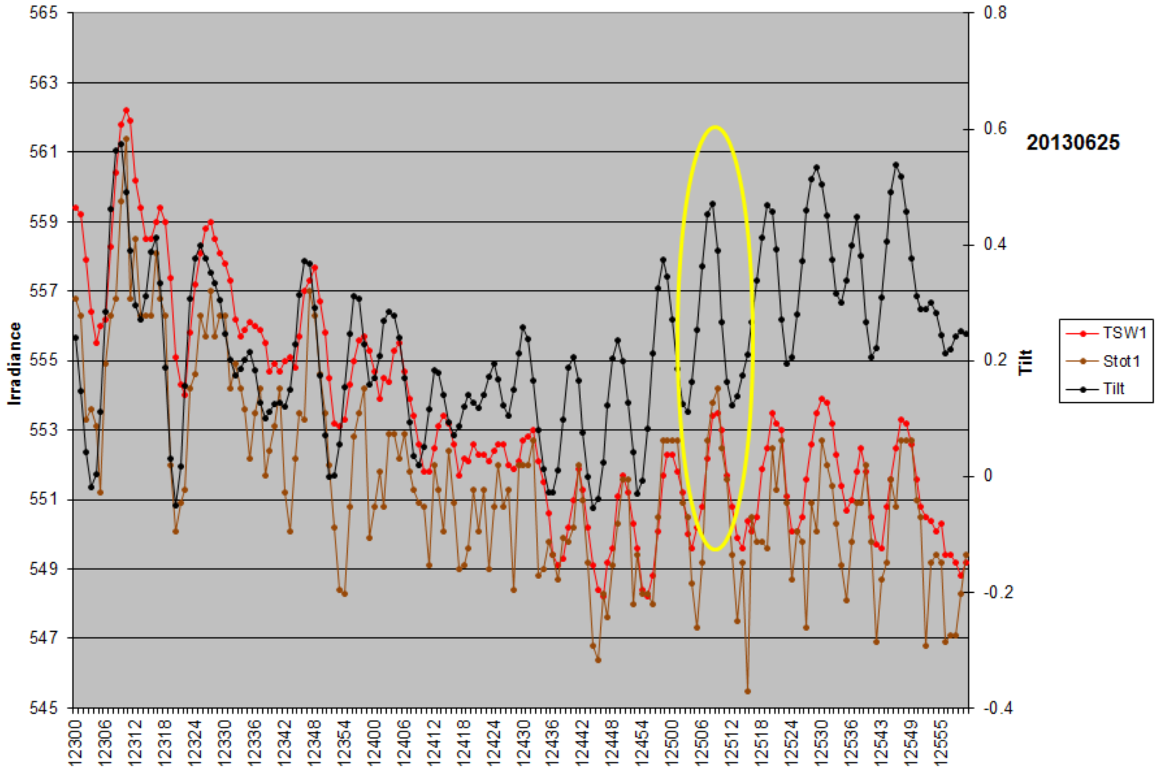

Figure 2. Close-up of MAGIC tilt (black) calculated from the navigation data and SPN1 (brown) and PSP (red) total SW radiometer data for June 25, 2013. The yellow oval highlights an example of timing offsets.

3.0 Publications and References

Long, CN, 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." *The Open Atmospheric Science Journal* 4(1): 78-87, doi:10.2174/1874282301004010078.

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