Woods Hole Oceanographic Institution

Upper Ocean Processes Group

Technical Note

Moored Observations of Precipitation Temperature

Although precipitation is known to play an important role in the buoyancy flux at the ocean surface by freshening the ocean, the heat flux associated with the precipitation is often ignored. When the rain droplet temperature is different than the ocean surface temperature, there is a sensible heat flux associated with the mass flux. Models and laboratory studies of the evaporation and temperature of a freely falling droplet of water suggest that the temperature of rain will be near the ambient wet bulb temperature (Kinzer and Gunn, 1951; Kincaid and Longley, 1989).

The demand for increased accuracy in the estimates of air-sea fluxes led to the development of the Precipitation Temperature Module (PTM) for the Improved Meteorological (IMET) package. This instrument was designed to measure rain droplet temperature and to be deployed on a surface mooring along with the traditional surface meteorological and radiation instrumentation.

The current design of the PTM is based on experiments conducted at WHOI in the fall of 1991. During these experiments a funnel from an R.M. Young Model 50202 Precipitation Gauge modified with temperature sensors was arranged, as in Figure 1, along with a temperature sensor located near the rain gauge and directly in the precipitation's flow. The sensor located directly in the precipitation's flow is continually being flushed with precipitation thermally uncontaminated by the funnel, and, therefore, provides a close approximation of the precipitation's temperature. Experimental results show that when a heavy precipitation event occurs the sensor located directly in the precipitation reaches a steady state value, and eventually all the temperature sensors reach this same equilibrium indicating that the funnel was at (or very close to) the temperature of the precipitation. These results indicated that a funnel with temperature sensors distributed as in Figure 1 measuring the thermal state of the funnel could be used to measure the temperature of precipitation during heavy precipitation events.

To improve the response time of the PTM, the R.M. Young funnel was replaced with a thin stainless steel funnel with less thermal mass. The stainless funnel quickly comes to equilibrium temperature as the rain water flows through, and the funnel temperature is sampled.

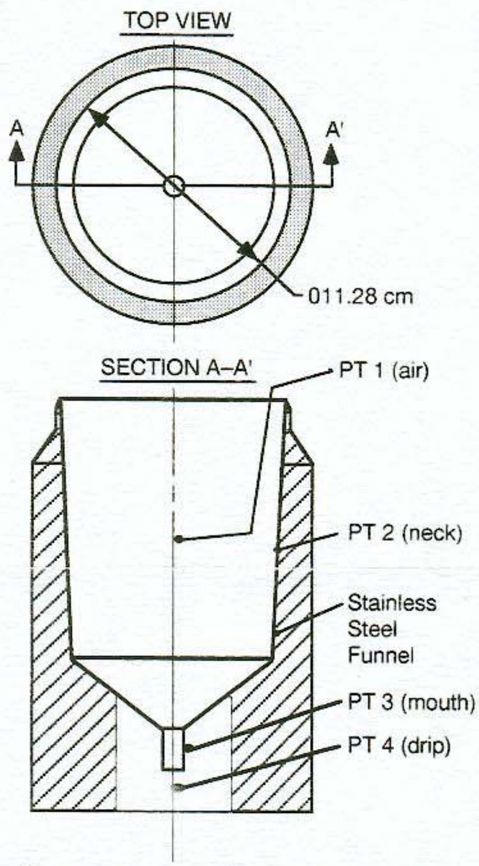

Figure 1. The Precipitation Temperature Module (PTM) was designed to measure rain droplet temperature.

The funnel was made of .005" thick stainless steel sheet and has a sampling area of 100 cm^2. At the base of the funnel is a 1cm diameter drip mouth which allows the precipitation to flow freely out the bottom. Four independent temperature measurements are made using fast response thermistors in a linear bridge configuration. The measurement range is 0°C to 38°C with 0.1°C accuracy and 0.0037°C resolution. Thermistor 1 (PT1) is suspended in the center of the funnel; thermistor 2 (PT2) is mounted halfway down the neck of the funnel; thermistor 3 (PT3) is located at the mouth of the funnel; and thermistor 4 (PT4) is located in the funnel outflow below the mouth (Figure 1). The thermistors are sampled at once every 10 sec and averaged over 1 minute before being recorded to the IMET data logger.

Electronics for the PTM consisted of the standard IMET PWCOM (Power & Communications) and SCM (Sensor Control Module) boards. A special low power analog front end board was designed to measure four independent channels of temperature with 10 bits of resolution. The analog front end was interfaced to a standard IMET module and custom firmware was written so the completed PTM module responded as a standard IMET module. By using the IMET boards the PTM was easily integrated into the suite of other IMET sensors on the buoy. Upon interrogation of the PTM by the IMET data logger, the PTM responds with four temperature measurements averaged over the previous minute.

As part of Tropical Ocean Global Atmosphere (TOGA) Coupled Ocean-Atmosphere Response Experiment (COARE), the PTM was deployed in the western equatorial Pacific ocean on the Woods Hole Oceanographic Institution surface mooring. This 3-m discus buoy was deployed at 156°E, 1° 45'S from October 21, 1992, to March 4, 1993, and carried a complete IMET package including the PTM. (Weller and Anderson, 1995).

A rain event observed as part of COARE is examined closely to illustrate the temporal evolution of the precipitation temperatures in relation to the wet and dry bulb temperatures, the sea surface temperature and the rain rate. This event actually consists of two closely spaced events (Figure 2). The dry PTM temperatures have a spread of 0.5°C that are grouped just below ambient air temperature before the event. The PTM temperatures then become closer together when the rain starts and drop down below the ambient air temperature, T_{dry}, to the wet bulb temperature, T_{wet}, at 23.3°C. After this first burst of rain, the PTM temperatures rise and spread apart. The warmest is PT1 which is suspended in the center of the funnel and has little thermal mass and, thus, can adjust more quickly back to ambient air temperature than the rest of the unit. The onset of the second burst of rain brings T_{dry} and PTM temperatures down again to T_{wet}. They all group together within 0.5°C for the duration of the rainfall. There is a 0.1°C drop in the sea surface temperature, T_s, during the event.

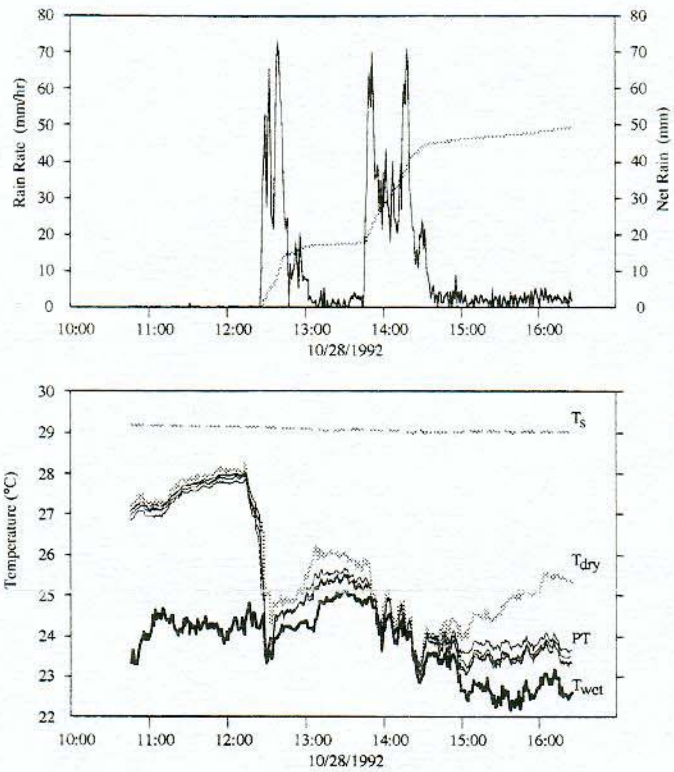

Figure 2. An example rain event. The top panel shows the rain rate and cumulative rain. The bottom panel shows the sea surface temperature (dashed, T_s), air temperature (gray, T_{dry}), the four temperatures from the PTM (thin black, PT) and the wet bulb temperature (thick black, T_{wet}).

Improvements in the long term stability and accuracy of the precipitation temperature measurements could be enhanced by using PRT's (platinum resistance thermometers) in conjunction with fast response thermistors. PRT's are inherently stable for longer periods of time than thermistors, but thermistors have a much faster response time than that of PRT's. By using both in the measurement the long term stability can be improved along with maintaining the quick response. The electronics could be redesigned to make the PTM completely self contained by reducing the power consumption, internally self recording and using an internal battery pack. A different choice of materials for the funnel could also yield improvements in the response time of the PTM to changes in precipitation temperature.

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