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Net radiometer for Martian surface energy balance

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Abstract

We have developed a net radiometer to measure the energy balance at the surface of Mars. To completely characterize the near surface atmospheric environment, a net radiometer is a necessary complement to the standard meteorological measurements of temperature, pressure, and winds velocities and directions. The net radiometer consists of a series of upward looking and downward looking visible and infrared detectors that, when mounted on a rover or lander, would provide energy balance measurements of the Martian surface.

1. Introduction

Due to its low surface pressure, the Martian atmosphere is a radiatively dominated atmosphere, unlike the Earth. As such, radiative heating and energy balance are critical components of the the Martian atmospheric processes. In fact, the net infrared energy is dominant over turbulent fluxes in the Martian energy budget [2, 3]. The accurate calculation of the near surface energy balance and the associated atmospheric heating is necessary to understand the Martian planetary boundary layer as well as the exchange of water vapor between the atmosphere and the subsurface.

The net solar and infrared flux measurements are required to calculate the surface atmospheric energy balance. Previous Mars meteorology investigations have measured temperatures, wind fluxes, and humidity fluxes using a variety of techniques [1, 5]. These measurements are insufficient for a complete energy balance calculation, however. To illustrate, we can write the general surface energy balance as

$$\partial_t E_s = F_{net} - F_{SH} - F_{LH} - F_G - F_M \qquad (1)$$

where the left hand side of the equation is the storage of energy in the surface, F_{net} is the net radiation at the surface, F_{SH} is the flux of sensible heat, F_{LH} is the flux of latent heat, F_G is the flux of energy into the surface, and F_M is the flux of energy due to melting and freezing [4]. For Mars, F_{LH} and F_M can be generated by either or both of carbon dioxide and water depending on the location of the planet, though generally these fluxes will be smaller than the other terms. Measurements from an air temperature sensor, ground temperature sensor, humidity sensor, and wind sensor would provide the information to determine F_{SH}, F_{LH}, F_G, and F_M. To completely capture the surface energy balance the net radiation flux must be measured. The acquisition of upward and downward thermal and solar fluxes allows the atmospheric heating rates to be calculated, as well.

2. Instrument Description

The net radiometer consists of a small number of upward and downward looking thermopile detectors that would be positioned on a rover or lander such that the group of sensors have a clear view of the sky or ground, respectively. The small, low power detectors provide a single analogue measurement of the radiative flux within a specified band pass. Each of these thermopile detectors is built and operated in a similar manner. The requirements on the electronics are few and primarily involve power conversion, analog-to-digital conversion, and operations commanding. The instrument is divided into two sensor units, one with an upward field of view and one with a downward field of view, and an electronics unit. The upward and downward looking sensor units have the same complement of solar and infrared, including wide band solar and infrared detectors along with a selection of narrow band detectors.

3. Detector Description

A thermopile detector is an electronic sensor that generates a voltage that is proportional to the temperature gradient between the thermopile and the local area. Thermopiles generally consist of numerous thermocouples bundled together. The thermocouple measures temperature by leveraging the thermoelectric effect, which occurs when a conducting material generates a voltage. If a dissimilar conductor is used to then mea-

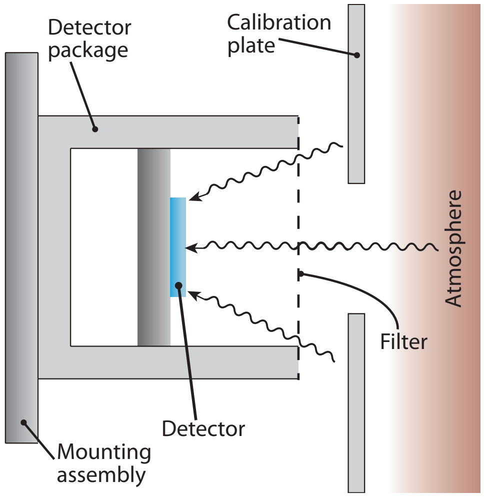

Figure 1: A diagram of the thermopile detector with calibration plate. This design is derived from previous NASA PIDDP development which directly lead to the technique used by the MSL REMS instrument [1].

sure this voltage, the combination of the two dissimilar conductors results in a voltage difference that is a proportional to the temperature. A filter in the field of view of the thermopile determines the bandpass detected, whether solar or infrared.

A key part of the net radiometer operation is the ongoing calibration of the detectors. The detector performance and accuracy will fluctuate with dust accumulation on the filters. Thus, the thermopile detectors require calibration both before flight and during operation. To meet this requirement, a high emissivity, low thermal mass plate will be placed in the field of view of each detector, as shown in Figure 1 to be used as a calibration plate. By heating this plate to a fixed known temperature, the thermopiles will detect a steady signal that will be consistent over time. With this calibration plate and an established analysis technique, our net radiometer will be able to frequently calibrate the performance of the detectors as a function of dust accumulation [1].

4. Summary and Conclusions

By leveraging the previous radiometer development work and involvement on the Mars Science Laboratory Rover Environmental Monitoring Station (MSL REMS) by McEwan and Richardson at Ashima Research [1] as well as the instrument development and flight operations experience of Rafkin and Soto at the Southwest Research Institute, we have developed a low risk instrument that will provide crucial observations of the near surface energy balance. This instrument will complement any future meteorological packages sent to the surface of Mars.

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