HIGH RESOLUTION MEASUREMENT OF PRECIPITATION IN THE SIERRA

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Measurement of precipitation, particularly in any highly irregular terrain as the Sierra, requires simultaneous and collocated measurement of both the vertical flux as a rain/snow rate together with a measure of the local wind speed. High resolution measurement further require fast response sensors for sufficient representivity, (better than 1 minute, at least) and size greater than hand size, having capability of measuring both rain or snow or any mix thereof with an uncertainty better than 1/100 inch/hr and a few m/s. The hotplate precipitation gauge, comprising a sandwich construction of two identical ridged plates, thermally and electrically separated by 2cm, is deployed horizontally and maintained at about 100C by intrinsic heaters. Controlled power(watts, measured as an absolute quantity) closely maintains temperature and provides a measure of precipitation by rapid evaporation latent heat. This dominates the heat economy, requiring selection of liquid or solid latent heat depending on air temperature. Wind convective heat loss occurs for the top plate and wind alone for the shielded bottom plate. Long term measurements may be combined to demonstrate a changing moisture climate through a frequency analysis of precipitation rate, as how much precipitation fell at different rates for selected periods. Choice may be as a frontal passage or a storm or a decade. The frequency analysis has advantage that local changes of terrain (grass, trees, buildings, parking lots, snow terrain) growing or decaying are excluded. A further advantage of the frequency analysis lies in providing insight into the physical processes and serves as a guide to design the hotplate system itself through the range needed to be covered. For example, in the high Sierra, most winter precipitation falls at about 4mm/hr with not much beyond twice that amount, useful to know for choice of power supplies. Similarly, in some sheltered lee regions, winds do not exceed 20 mph compared with crests where 100mph is more likely. A further advantage of the hotplate system is that birds, having tried to settle on it once, learn not to return. The system is designed to keep data during a power outage and to revive itself when power returns. Data may be transferred and plotted remotely as desired. In the high Sierra choice of site is paramount as it is inconvenient to dig out the system in mid season. Uncertainties arise on occasion by hail bounce or raindrop splash, estimated to be minimal considering other features of measurement of precipitation. Dual systems (one hotplate above the other) provide information on blowing snow and lead to characterization by a 1 minute Richardson number by incorporating a vertical profile of temperature and horizontal windspeed. This research was supported by NSF grant ATM-0224865, Physical and Dynamical Meteorology Program.

Measurement strategies for precipitation in mountainous terrains appropriate for Sierra Nevada (as in California) and similar locations:

The hotplate instrument, conveniently mounted 1 or 2 m above the surface with its plane horizontal is ideal for a single location measurement. It is subject to a limitation that it not become buried during the snow season.

The overall rationale lies in differentiation for a likely westerly flow (for example) related to the flow over the crest, with possible locations for reverse upslope flow in a lee eddy with possibility of several instruments located in the upper stagnation region of the eddy, downstream stagnation of the eddy, in the eddy itself and ideally down-stream of the flow in the beginning of the foehn descent.

The instruments need to be ganged to ensure and maintain a common measurement time; each instrument measures, as collocated quantities, precipitation and wind speed with one minute resolution. The time dependence of the eddy location and its variability together with local precipitation as snowfall or rain depending on air temperature.

Such measurements are necessarily limited in a single flow direction for a beginning investigation. Deployment further downslope would give measurements under thermally layered conditions. Measurements result from a unit deployed near Soda Springs over the last few years (Fig. 1) and demonstrate difficulties of maintaining a continuously functioning system under rain, wet snow and a freezing/thawing environment with continuous remote communications.

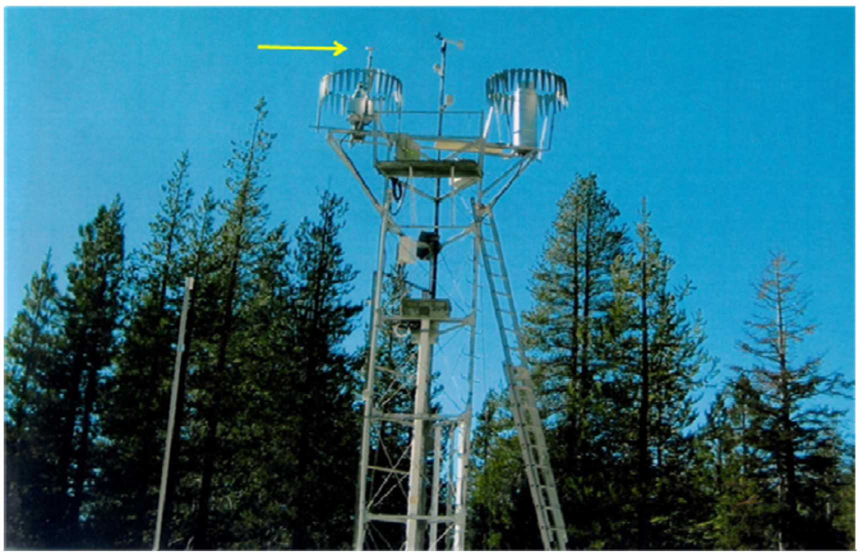


Fig. 1. Hot plate deployment (top left arrow, above altershield) at Soda Springs, CA, Berkeley Snow Laboratory, showing other instrumentation mounted to avoid winter-time snow.

Principles of operation and deployment:

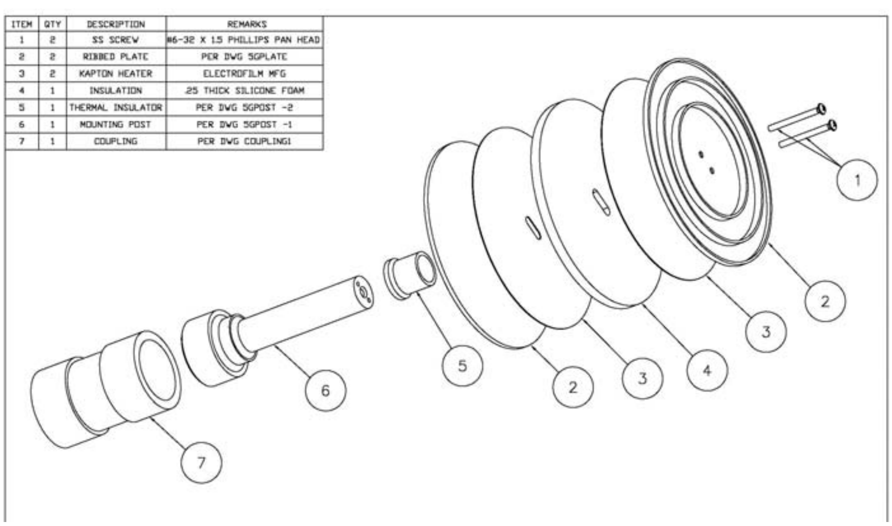
1. Measure precipitation on a flat area of level ground by having a subsurface cavern with a gridded top and leading to the subsurface collection system with remotely available output. Choice of grid size prescribes surface roughness. Sensor (as a standard weighing gauge or a hotplate top element of similar dimensions as a surface roughness element, minimally influencing airflow through surface roughness at collection site .Such an arrangement does NOT solve the problem.

2. Hotplate strategy: as a thin sandwich, to measure rain evaporation by heat flux and wind speed by heat transfer in airflow over the hot (about 100°C) solid upper surface. This is

referenced to the shielded (no precipitation) under surface maintained at near the same temperature and the same roughness with ridges to prevent particle roll-off on top (Figs. 2a,b,c). The upper airflow regime is closely comparable with the lower airflow regime in all respects for sensible heat, with flow Re measured by the shielded bottom plate, as wind speed with air temperature and pressure measured separately as required. Second order changing radiation effects may need calibration, to be done occasionally. The sensor may conveniently be located at 1, 2 or more meters height and may be duplicated at two or more levels to provide a local Richardson number; inter-comparison presents difficulty as large systems interfere with flow (Fig. 3).

(2a)

Fig. 2a,b. Detail of hotplate, above and below showing (red) insulation of upper and lower (shielded) hotplates. Central support ensures no local sensitivity to wind direction.



ITEM	QTY	DESCRIPTION	REMARKS
1	2	SS SCREW	#6-32 X 1.5 PHILLIPS PAN HEAD
2	2	RIBBED PLATE	PER DWG 5GPLATE
3	2	KAPTON HEATER	ELECTROFILM MFG
4	1	INSULATION	.25 THICK SILICONE FOAM
5	1	THERMAL INSULATOR	PER DWG 5GPOST -2
6	1	MOUNTING POST	PER DWG 5GPOST -1
7	1	COUPLING	PER DWG COUPLING1

(2b)

Fig 2c. Hotplate to ensure a 1 minute response for high snow rates with extreme blizzard conditions (below).

(2c)

3. The supporting central post leads to a slight flow asymmetry to be assessed empirically. Calibration is achieved by hand application of water to upper and lower plates by hypodermic over a known time period (ml over 50 seconds). This only needs to be done once; the lower plate for wind only demands some skill in application to inhibit drip.

Fig. 3. Hotplate mounted well above altershield and comparison gauge.

4. For a mountainous terrain, with a component of flow normal to the ridge direction, several (two or more) sequential surface units may be necessary to distinguish reverse flow eddies changing in location, magnitude and size away from the crest and the changing location of precipitation. Previous years' observations of lying snow would provide insight into optimum location for measuring sites (Fig 4).

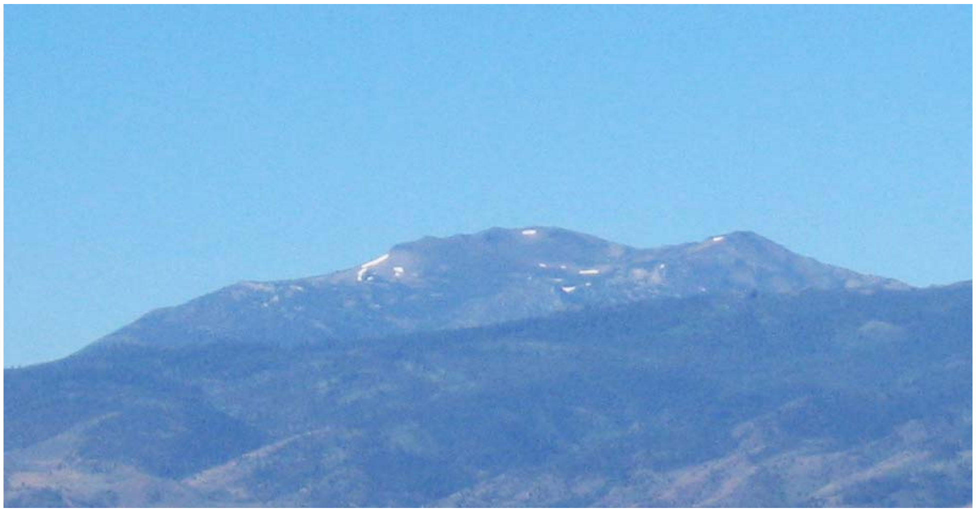


Figure 4. View from Ice Physics Laboratory of Mount Rose, Nevada, July 2010, of residual winter snow as an indicator of deposition in downwind reverse flow. View approximately to south.

Considerations in deployment strategy:

- The Jevons effect has been long known (Jevons, 1861). It results in precipitation undercatch following rising of otherwise horizontal airflow by passage over the gauge itself (considered as an obstacle), resulting in vertical velocity greater than precipitation terminal fall speed and so fraction of precipitation particles fail to enter the gauge.

- An estimate of such uncertainty is available from a measure of the windspeed at the gauge location. Strategies as use of an alter shield or DFIR system have been extensively used to oppose a downward airflow but arguably must only work for a particular wind speed. Ability to measure wind speed at the same location as precipitation bypasses these difficulties and is achieved in the hotplate device alone through collocation of precipitation and wind speed measurement in a convenient dimension of 13cm in horizontal and 2.5cm in the vertical.

- Such a device is capable of providing a measure of mass flux (liquid, ice or any mix thereof), through this region, defined as the operational space, uninfluenced by and - more importantly not influencing - the ambient airflow.

- Measurements may be further displayed as a frequency distribution, Fig. 5.

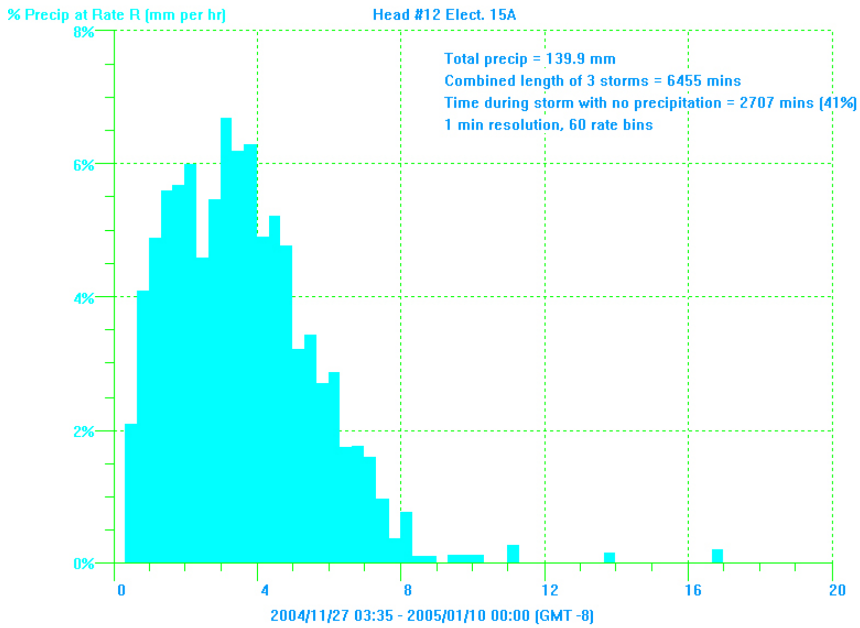


Fig. 5. Frequency distribution of snow fall rate from a series of snow storms combining all data from three storms leading to specific analytical relationships.

- We are herein dealing with a guiding principle that the measurement itself must minimally influence the quantity to be measured.

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