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A simple one-dimensional Cold Cloud-Pixel-Raingauge model

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In order to gain some insight into the statistical behaviour of rainfall measured with a raingauge and cold cloud duration obtained from a geostationary satellite, the simple model illustrated in fig. A1 was developed. The model is in line with other simple storm models used to study raingauge-raingauge correlations as a function of inter-station distance and storm characteristics (Stol, 1986).

The reader is also referred to studies by Bellon and Austin (1986), Shih (1990) and O'Sullivan et al. (1990) who compare raingauge measurements with satellite estimates through the tracking of individual cloud (O'Sullivan and coll. use pattern recognition techniques to identify specific clouds). With individual clouds, up to 85% of the raingauge variance can be accounted for.

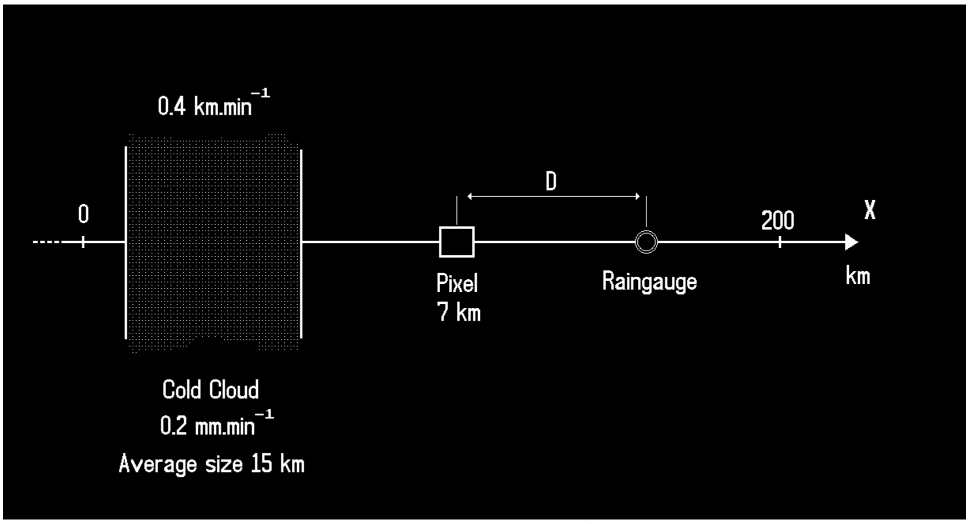

Figure A1: a simple one-dimensional model of rain-bearing cloud, pixel and raingauge. Refer to the text for details.

In the present model, clouds are generated at a random position on the X axis and travel at a constant velocity of 0.4 km per minute. Depending on their initial position, the clouds will pass either the pixel, located at the centre of the axis, or the raingauge, or both, or neither. It is assumed that all clouds actually generate rainfall (*i.e.* it is assumed that rainfall-producing clouds can be identified with certainty; this point will be qualified below).

When a cloud reaches the right end of the axis, a new cloud is generated. Every minute (the time step adopted in the model), the model examines whether the cloud is directly overhead the pixel or the raingauge, and this allows the exact determination of the areal average of the precipitation fallen over the pixel and of that recorded in the raingauge.

To simulate the observation of the surface of the earth at regular intervals by a geostationary satellite, a sampling frequency is defined at which the amount of clouds over the pixel is assessed: if it exceeds 50% of pixel area, the cold cloud counter is incremented (cold cloud duration is increased by the sampling frequency). Together with the sampling frequency, the distance between the raingauge and the centre of the pixel constitute the two main variables of the model.

It should be noted that cold cloud size (CCS) is imposed a normal statistical distribution with a given mean and standard deviation; similarly, rainfall intensity (RI) is characterized by its average value (RIAvg) and standard deviation (RIStd). When RIStd is chosen slightly smaller than RIAvg (about two thirds) and CCSStd is just under CCSAvg, then a realistic behaviour of the model can be obtained when negative CCS and RI are reset to zero: some clouds do not generate any precipitation and, most important, the statistical distribution of the rainfall recorded in the raingauge approx. follows the standard distribution of rainfall data, *i.e.* the incomplete gamma distribution.

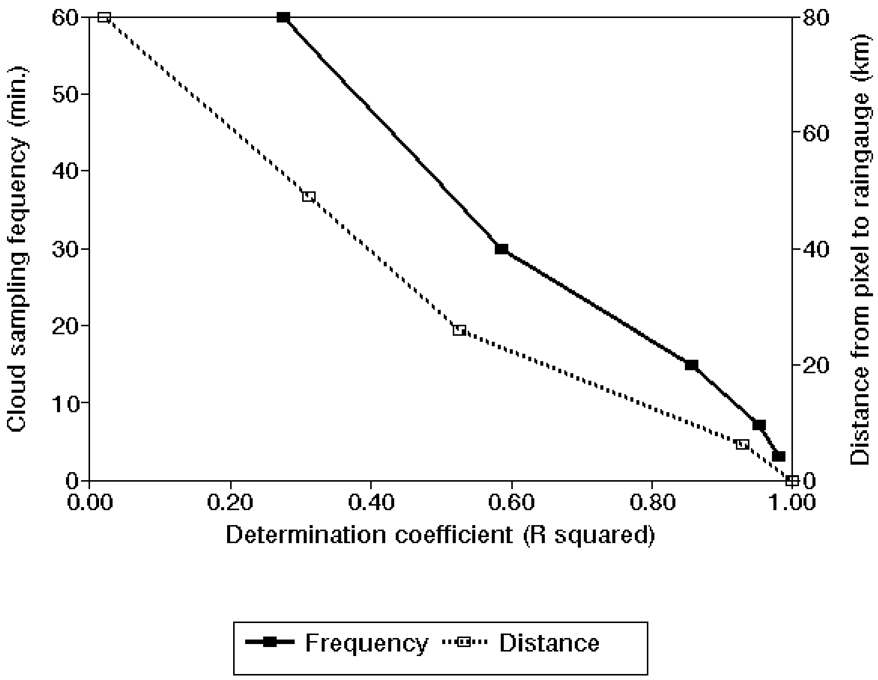

Figure A2: correlation (measured as the coefficient of determination, abscissa) between simulated average dekad pixel rainfall and (i) a distant raingauge (km, dotted curve, right axis), (ii) cold cloud duration over the pixel sampled at different intervals (minutes, solid curve, left axis). The figure is based on a simulation covering 500 days accumulated into 50 10-day periods.

This point is regarded as a first indication that the model is qualitatively correct. A second one is obtained by comparing pixel-raingauge correlation curves with actual situations in Kelbe (1987).

The model was run for 500 days under a number of different sets of sampling frequency and distance between pixel and raingauge. The rainfall amounts and cold cloud durations were accumulated over 10-day periods and the 50 sets of data were subsequently used for the statistical evaluation.

Fig. A2 illustrates the simulated correlation between dekad average pixel rainfall and rainfall from a distant raingauge (dotted "distance" curve) and correlation between average pixel rainfall and cold cloud duration for different sampling frequencies (solid "frequency" curve).

As the correlation between average pixel rainfall and a raingauge located at the centre of the pixel is close to 1.00 the values given in fig. A2 for the correlation between average pixel rainfall and a distant raingauge are virtually identical as the correlation between distant raingauges.

The "error" introduced by cloud sampling can thus be compared with the error due to raingauges constituting representative samples only of their immediate surrounding.

According to fig. A2, and within the limits of the model, the error introduced by a cold cloud sampling frequency of 30 minutes (coefficient of determination about 0.60) is the same as that due to a raingauge being distant 20 km; conversely, to achieve the same accuracy as a raingauge at 40 km of the area of interest, a cold cloud sampling frequency of 50 minutes would be required.

Raingauge-pixel distance	Sampling frequency (minutes)				
	3	7	15	30	60
0	1.00	0.94	0.85	0.36	0.36
6	0.88	0.86	0.79	0.69	0.30
26	0.55	0.45	0.56	0.34	0.09
40	0.22	0.32	0.16	0.24	0.03
80	0.00	0.12	0.05	0.04	0.10

Table A1 : correlation between simulated Cold Cloud Duration (CCD) over a 7 x 7 km pixel and the amount of rainfall recorded in a raingauge, as a function of CCD sampling frequency and increasing distances (0 to 80 km) between raingauge and the centre of the pixel. The simulation covers 500 days and the averaging period was 10 days.

A direct implication of the above is that, for a country the size of, say Burkina Faso (274,200 sq. km), 685 raingauges (274,200/400) would be required to achieve to achieve the same "accuracy" as cold cloud sampling every 30 minutes.

Tab. A1 above presents the combined effect of raingauge-pixel distance and sampling frequency for rainfall accumulated of ten-day periods. The model is somewhat more optimistic than reality in the semi-arid areas (compare, for instance, with the data presented by Kelbe, 1987). The following reasons can be listed: rainfall intensity-duration effects are not accounted for and rainfall producing clouds cannot be identified with certainty.

References

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