PRECIPITATION PHASE DISCRIMINATION BY DEW PPOINT AND AIR TEMPERATURE

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ABSTRACT

Correctly reported precipitation phases are crucial for estimation of snow storage in hydrological, regional and global climate models. Precipitation phase is especially critical for models simulating processes in tree canopies, since the canopy storage capacity is about one order of magnitude larger for snow than rain. The number of manned meteorological stations is decreasing, making determination of precipitation phase more difficult. Most hydrological models use an air temperature threshold to separate rain from snow, but there are indications that a dew-point temperature threshold might work better. This study utilized forty-five years of three-hour man-made observations for nineteen Swedish station ranging from 55˚N to 68˚N consisting of precipitation mass and phase, air and dew point temperatures. Precipitation events were classed as snow or rain, excluding mixed precipitation, were used for the initial analysis. Air temperature was found to be a better indicator of precipitation phase then dew point temperature. On occasion 0˚C is used as an air temperature threshold, but if the air temperature rain/snow threshold 0˚C is replaced by 1.0˚C the misclassified precipitation would be reduced by almost half in Sweden. Further analysis to identify mixed precipitation, totaling 16% of the precipitation is also included.

INTRODUCTION

With a growing trend to replace weather observers with automated systems, parameters must be identified to determine precipitation phase by surface observations. This study will determine a rain/snow threshold using 45 years of data from 19 manned weather stations in Sweden. A rain/snow threshold ignores mixed precipitation as there is no direct way to quantify the amount of liquid and solid proportions of these events. In Sweden mixed precipitation makes up 16% of the total precipitation. This makes an obligatory pursuit for parameters to distinguish between rain/snow/mixed precipitation necessary.

Correct identification of a rain/snow threshold is very important for the functioning of models that forecast floods, water balances and climate change. In flood prediction and water balances, the phase of precipitation determines how much water will contribute to runoff, add to the snow water equivalent, or sublimate in trees (Kokkonen et al., 2006). Climate change models also depend on reliable rain/snow thresholds to account for changes in amounts and phase of precipitation due to expected seasonal air temperature changes (Davis et al., 1999).

There are numerous methods to separate rain/snow/mixed precipitation, and one simple approach is to assume all precipitation below 0˚C is solid, above 2˚C is liquid and everything between is mixed (Fuchs et al. 2000). However, in a study by Matsuo et al. (1981), relative humidity was used as a parameter to separate rain/snow/mixed precipitation. They used four years of data separated into different seasons and critical humidity lines were plotted on a relative humidity temperature graph as to have only snow below one line, only rain above another line and rain/snow/mixed precipitation between the two critical humidity lines. Matsuo's study indicates that at the same temperature, snow will occur at a lower relative humidity than rain and that the temperature range for mixed precipitation becomes narrower as relative humidity drops (Matsuo et al., 1981).

After manned stations were replaced by automated stations in Switzerland, the rain snow threshold decreased by 1˚C (Braun, 1991). The goal of this study is to determine a rain/snow threshold and parameters from manned stations to be utilized in correcting snow models. Hopefully information such as this will be given consideration for algorithms that determine precipitation phase at automated stations.

MATERIALS AND METHOD

Three-hour observations, supplied by the Swedish Meteorological and Hydrological Institute (SMHI), from 19 manned weather stations (Figure 1) for 01 JAN 1961 - 30 NOV 2006 were used. The observations included the

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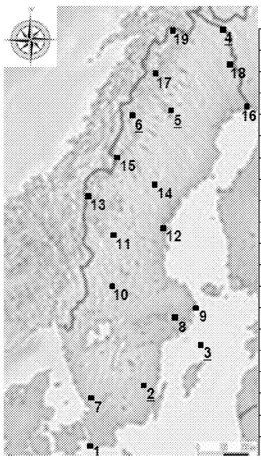
date/time, total precipitation for the period, three weather identification groups listed in no particular order, average air and dew point temperatures. The observations for each station were separated into rain/snow/mixed precipitation phases. Of note, freezing rain was considered solid precipitation since it freezes on contact, and ice pellets above 8˚C were considered rain since hail from spring and summer thunderstorms would only affect year round ice sheets. All observations with less than 0.1 mm of water equivalent were removed. Information about the presence of snow cover on the ground was not given, so the saturation vapor pressures over water (*ES*) as a function of air temperature ˚C (*T*) and dew point temperature ˚C (*TD*) were calculated:

$$ES(T) = 6.11 \cdot \exp\left(\frac{2.5\cdot10^{6}}{461.5}\cdot\left(\frac{1}{273.25}-\frac{1}{T}-273.15\right)\right). \qquad (1)$$

Relative humidity (*RH*) for each observation was calculated using,

$$\text{relative humidity} = \frac{ES(TD)}{ES(T)}. \qquad (2)$$



MAP KEY

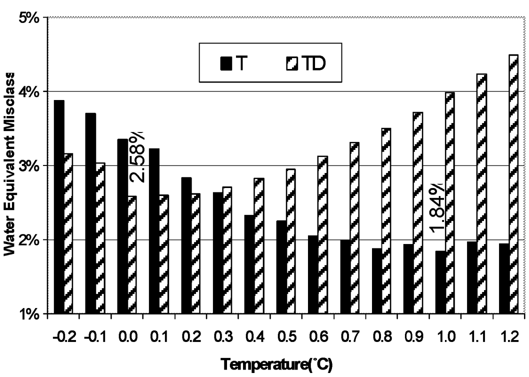
Station Code	Location
1	FALSTERBO
2	MÅLILLA
3	GOTSKA SANDÖN
4	KARESUANDO
5	GUNNARN
6	HEMAVAN
7	TORUP
8	STOCKHOLM
9	SVENSKA HÖGARNA
10	MALUNG
11	SVEG
12	SUNDSVALLS FLYGPLATS
13	STORLIEN-VISJÖVALEN
14	JUNSELE
15	GÄDDEDE
16	HAPARANDA
17	KVIKKJOKK-ÅRRENJARKA
18	PAJALA
19	KATTERJÅKK

Figure 1. Map of Sweden, the location of weather stations are marked with black squares, the first six stations listed in the map key were used for further analysis of precipitation phase change relationships.

Precipitation events by phase were plotted on a T vs. RH graph for three stations in Northern Sweden, Karesuando, Hemavan, and Gunnarn, and three stations in Southern Sweden, Falsterbo, Gotska Sandön, and Målilla. Precipitation phase percentage vs. T/TD graphs were also produced to illustrate the gradual or immediate relationship between precipitation phase of events over a range of temperatures, for the afore-mentioned stations.

RESULTS

The rain/snow threshold found for air temperature was 1.0˚C with 1.8% misclassified precipitation (Figure 2). The threshold for dew point temperature was 0.0˚C with 2.6% misclassified precipitation. At 1.0˚C the



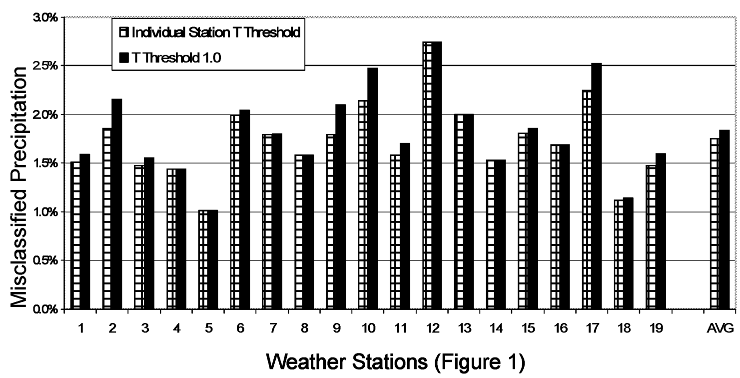
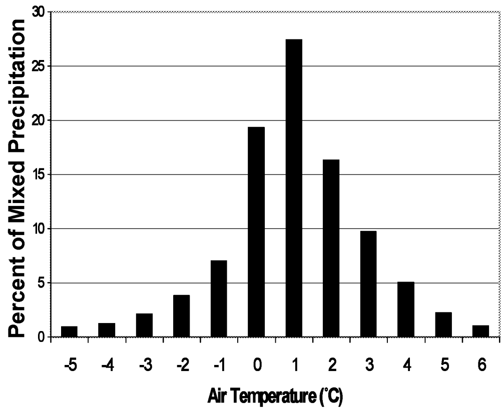


Figure 2. (left) Percent of misclassified precipitation for air (black), and dew point temperatures (striped). The values given at 1.0˚C and 0.0˚C are the percent misclassified precipitation at the threshold for air and dew point temperatures respectively.

Figure 3. (right) Misclassified precipitation using the overall rain-snow threshold of 1.0˚C (black) and the best individual rain/snow threshold (plaid) for each station in Figure 1.

misclassified precipitation was 52% rain and 48% snow. Individual station threshold temperatures compared to the threshold temperature of 1.0˚C yield a maximum decrease in misclassified precipitation of 0.3% at Sveg, with no difference at six stations (Figure 3). In this study individual station threshold temperatures are on average 0.1% more accurate than a set threshold temperature of 1.0˚C.

In Sweden, 16% of the precipitation is mixed. Most of which occurs between the temperatures of -2˚C and 4˚C with a maximum at 1˚C. The mixed precipitations seems to have a bell shaped curve when all stations are taken together (Figure 4) but this does not seem to hold true for the individual stations which all have their own unique precipitation phase distributions (Figure 5).



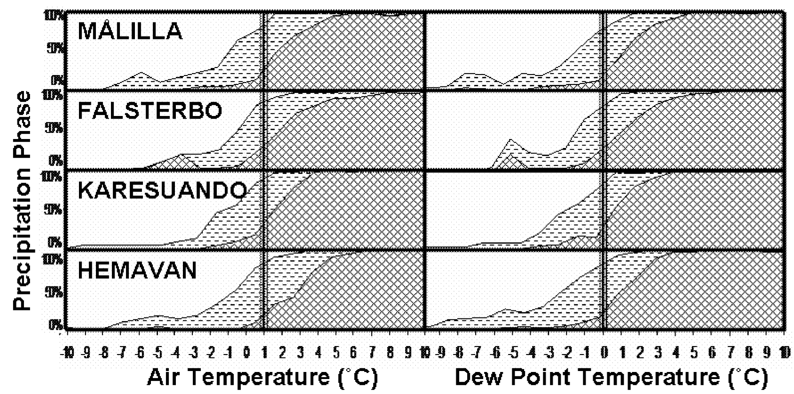


Figure 4. (left) The temperature distribution of mixed precipitation for all locations together.

Figure 5. (right) Precipitation phase (snow is white, rain is crossed pattern, mixed is dashed) distribution for southern stations (Målilla and Falsterbo) and northern stations (Karesuando and Hemavan) versus T (left) and TD (right). Thick black line represents the average threshold temperatures.

Precipitation events plotted on RH vs. T graphs show that mixed precipitation and snow can occur at the same temperatures as rain, but the rain usually occurs at higher RH. There are wide rain/snow/mixed areas so it is difficult to draw critical humidity lines that separate rain and snow only zones (Figure 6).

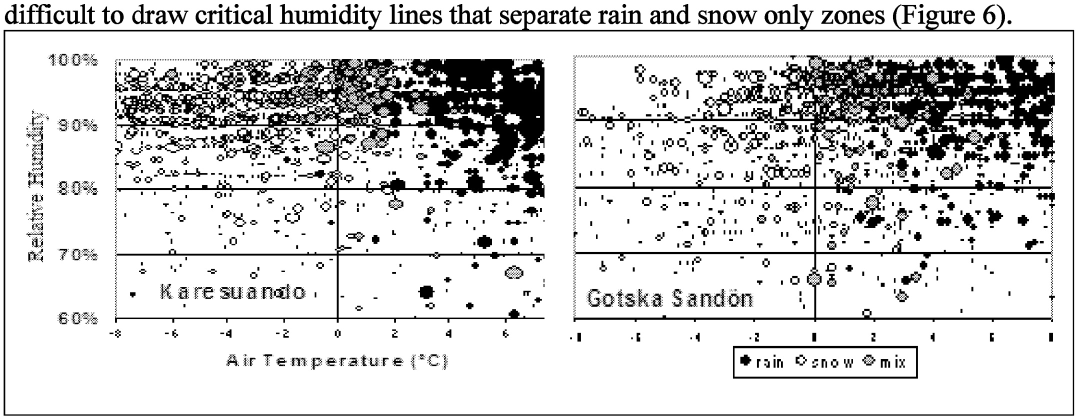


Figure 6. RH vs. T graphs with the water equivalent of precipitation events indicated by the size of circular plots. (Graphs created by Virginie Irrien)

DISCUSSION

The air temperature threshold (ATT) of 1.0˚C was found to have 30% less misclassified precipitation than the dew point threshold (DTT) of 0.0˚C. ATT had less misclassified precipitation than DTT at all 19 observation stations, spanning from mountain areas to islands, from Southern (55˚N) to Northern (68˚N) Sweden. ATT = 1.0˚C had comparatively 45% less misclassified precipitation than the occasionally used ATT = 0.0˚C.

Most models use an ATT (Kokkonen et al., 2006). The same ATT as found here is also used in Iceland (Aoalgeirsdottir et al. 2006). In the 1950's the U.S. Army Corps of Engineers defined ATT as 1.1-1.7°C with the understanding that ATT varies between locations (Yuter et al., 2004). However the ATT of 0.0˚C was commonly used through the late 1980's and is also found in snow models developed in the late 1990's (Goodison et al., 1998).

No correction for gauge undercatch of precipitation due to wind errors was performed. These errors can range from 1.02-1.14 for rain and from 1.05-1.80 for snow (Kokkonen et al., 2006). The wind errors for rain and snow are usually similar around the threshold since wet snow approaches the density of rain at these temperatures. Thus, snow missing the gauge will affect the total amount of snow in a model more than it will affect the rain/snow threshold.

Mixed precipitation appears evenly distributed with a maximum volume at 1˚C, the same temperature that was found by ATT. Unfortunately, this does not excuse the exclusion of mixed precipitation as a source of error in the determination of a rain/snow threshold. A sharp transition from rain to snow oversimplifies the importance of the 16% of mixed precipitation found in this study. In a similar situation where mixed precipitation was prevalent between 0˚C and 1.1˚C, a weather radar found a transition from snow to rain dominance in terms of volume fraction at 0.5˚C (Yuter et al., 2004). However, without radar it might be possible to account for this error by determining the mixed precipitation average fraction of water and ice as a function of temperature through a calorimetric study

On RH-T graphs there is a difference in the distribution of mixed precipitation between colder and warmer stations. In cold stations it seems possible to separate a rain only zone, but his is not possible in the southern stations which might have a stronger maritime influence that the cooler stations. In both warm and cool stations the mixed and snow phases overlap to a great extent, giving rise to uncertain critical humidity lines. So, in contrast to Matuo et al. (1981), we could not identify distinct critical humidity lines. In Matsuo's study the data was separated into different seasons, which had different equations for critical humidity lines. Using data from all seasons rather than separating seasons may have decreased the effectiveness of critical humidity lines as a parameter in this study.

CONCLUSION

An ATT of 1.0˚C performs much better than a DTT of 0.0˚C for classifying precipitation type. With only 0.1% difference in misclassified precipitation between an ATT of 1.0˚C and ATTs calculated at individual stations, 1.0˚C performs well as an ATT for Sweden, possibly for other high latitude countries, and should be tested for middle and lower latitude areas.

Parameters for changes between rain/mixed/snow based on surface observations are difficult to identify since a change in precipitation phases is a result of the thickness of temperature layers in the lower troposphere. However, the misclassification of precipitation when using threshold temperatures can be reduced by secondary parameters using knowledge regarding regional weather regimes.

Relative humidity as a secondary parameter did not produce good results when data from the whole year is used. Perhaps a follow-on study into the use of RH as a changing parameter with months would produce better results. A better approach might be to identify logic equations that take into account wind shifts or precipitation rates characteristic of different fronts. A distinction between fronts will provide valuable information about expected atmospheric conditions above a station.

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