MODULE 4.2E

SHORT RANGE FORECASTING OF CLOUD, PRECIPITATION AND RESTRICTIONS TO VISIBILITY

Precipitation Amount and Type

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1. QUANTITATIVE PRECIPITATION AMOUNTS (QPF)

One of the most difficult questions to answer when forecasting precipitation is "how much?". Related to amounts are the questions "how intense?" and "how long?".

Amounts and intensities hold particular importance to the public in winter when the precipitation is freezing or frozen. Liquid precipitation amounts take on their greatest importance when associated with severe weather events such as flooding. Because of this, many of the forecast techniques available cover only winter precipitation. Fortunately, many of the procedures for forecasting winter precipitation can be adapted fairly readily to the rainfall problem since rain and snow depend physically on the same mechanisms. The exception occurs when using empirical techniques for the QPF problem.

Solving the QPF problem is at least a two-step process. The first step is to forecast the downstream areas most likely to be affected by large amounts of precipitation. The second and more difficult task is to give quantitative forecasts. When forecasting areas or amounts, the mainstays are synoptic correlation, extrapolation, storm climatology, and a knowledge of local processes. A knowledge of local processes can prove, at times, quite significant in explaining a fair portion of the inherent characteristic variability of precipitation amounts.

For very short term forecasting of areas and amounts of significant precipitation, extrapolative techniques have utility. When forecasting on longer time frames, the combination of synoptic correlation techniques and modelling of significant precipitation areas become more common approaches.

Traditionally, most approaches to the QPF problem concentrate either on storm tracking or on thermodynamic considerations. The techniques that employ thermodynamic fields generally address winter precipitation. Techniques that use storm tracking, on the other hand, are applicable for all seasons but work better when dealing with wintertime precipitation. In general, QPF techniques that are applied to summertime precipitation tend to have less success than when applied to wintertime precipitation. The summer QPF problem is sometimes the more difficult one to predict because, in this season, most large precipitation amounts result from convection and less organized weather systems. In winter, large precipitation amounts usually result from organized weather systems having strong dynamics. In general, the more organized weather systems with the stronger dynamics prove themselves more consistent and amenable to QPF techniques than do the weaker systems.

The most successful approaches to QPF are those that, in some way, take into account the processes that are producing the precipitation. Large amounts of synoptic precipitation, for example, can be expected under circumstances different from those supporting large convective precipitation amounts. Often, a knowledge of the situations most conducive to large amounts (modelling the weather) can prove invaluable to the forecaster.

Synoptic scale continuous precipitation is produced, in most cases, under relatively stable conditions and with large scale lift processes at work. The heavier amounts of synoptic precipitation tend to be associated with additional factors such as significant orographic lift or instability embedded above a frontal surface. Large quantities of deep convective precipitation, on the other hand, are mainly associated with cold fronts and squall lines. At times, deep convection in warm sectors (e.g. flow off the Gulf of Mexico) can produce large precipitation amounts. Other times, problems with amounts can arise from deep convection associated with a cold trough behind a cold front or near the centre of a cold low. As seen earlier, winter convective activity in the form of snowsqualls can give significant precipitation amounts and intensities.

Finally, the amounts associated with boundary layer precipitation tend, on average, to be less. Any significant amounts that result are found mainly in upslope or onshore flows and are associated with light intensifies such as light drizzle or freezing drizzle, or light snow. In such cases, orographic features are most likely to cause any variations towards the heavier amounts.

Storm tracking

Since deep or deepening cyclones can be heavy precipitation producers, storm tracking research has tended to concentrate on identifying certain preferred regions of cyclones and their associated synoptic features that favour heavier amounts. The guidelines given below represent a selection of predictors that should, in most cases, be adaptable to all types of precipitation. The predictors were originally derived for areas of maximum snowfall.

- Various researchers have found that when heavy amounts of precipitation (snow) are forecast during the next 24 hours, the maximum should be located near the 18 hour position of the surface low, and within 2 latitude degrees to the left of track.

- Another useful rule for 24 hour amounts is to place the maximum precipitation area near the 18 hour position of the forecast vorticity maximum, and within 4 degrees latitude to the left of its track.

As mentioned earlier, the results of storm tracking studies may be more reliable for forecasting winter precipitation than for the summer case; the stronger moisture and dynamic fields of winter allow the snow QPF problem to be more ‘treatable’ by storm climatology. Beyond the very short term, synoptic precipitation amounts generally tend to be the most ‘forecastable’ by QPF techniques. Convective precipitation amounts are particularity difficult to predict, partly because the amounts can be so variable over an area. When significant convection is expected, forecasts are usually worded in such a way as to mention heavy intensities, local downpours, perhaps some flooding, and other significant weather. Forecasts that give the specific sites most likely to be affected by large amounts of convective precipitation tend, by necessity, to be very short range and to be heavily based on radar and satellite information, as well as on upstream observations.

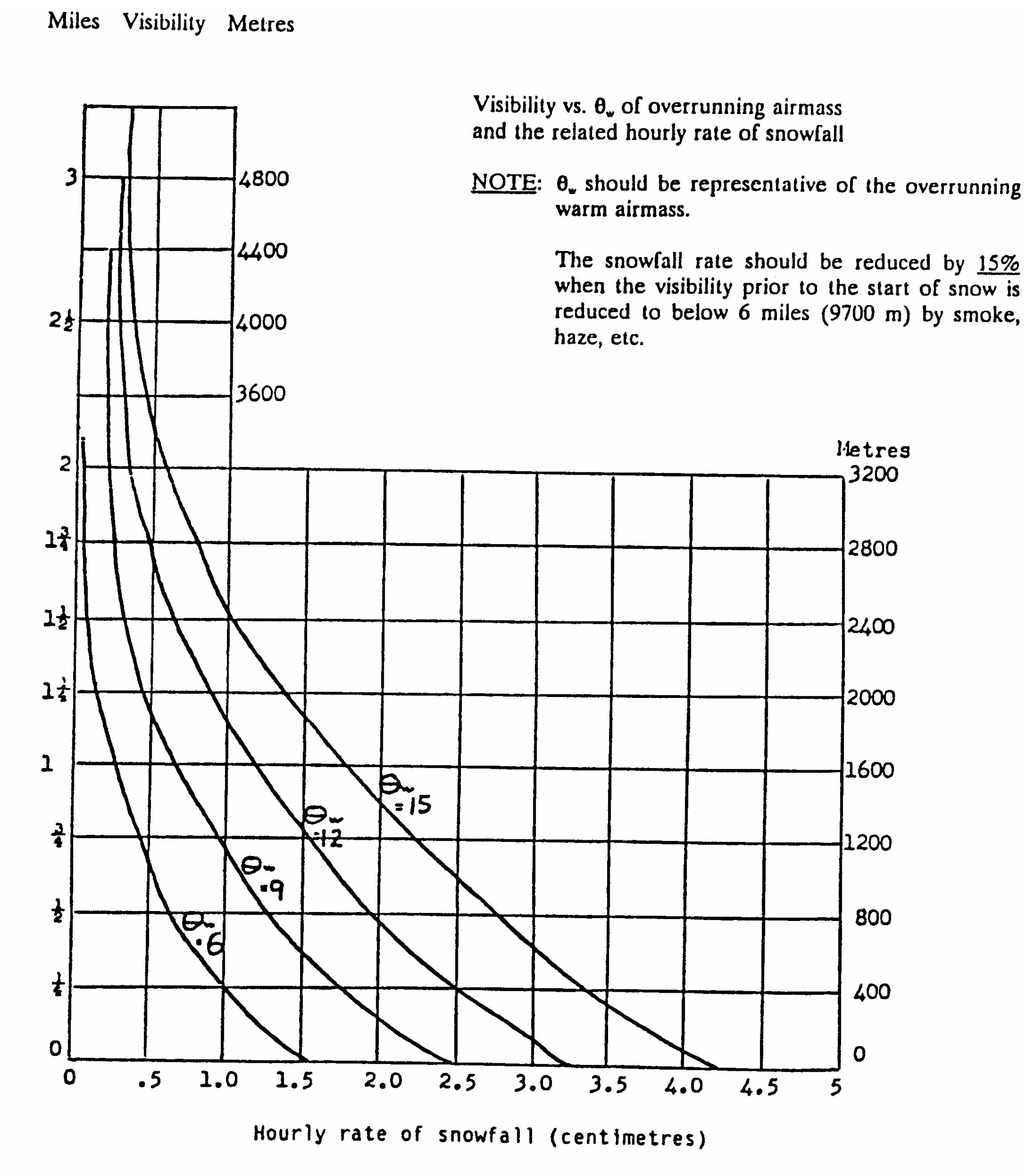

Figure 1. Snowfall rate Nomogram.

Thermodynamic considerations

Various diagnostic studies using thermodynamic fields have shown merit in dealing with the winter QPF problem. Such studies indicate that certain thickness bands, for instance, correlate well with maximum snowfall areas. One study from the Maritimes, for example, found that a significant proportion of cases of heavy snow occurrence tend to be correlated with a 1000-500 mb thickness of 5340 m. For western Canada, thickness correlations from the 850-700 mb thickness band of between 1500 and 1530 m work well in delineating heavy snow intensities (and amounts, if prolonged). The thickness correlation that works for a given locality and type of storm at any time tends to vary.

Freezing rain

Freezing rain in significant quantities poses a definite winter hazard. Large quantities of this precipitation can prove crippling to transportation. It is important to note, though, that heavy rates of freezing rain rarely occur, while moderate rates occur infrequently and tend not to last long. The heavier rates tend not to persist due to the rapid eroding of the ground based subfreezing layer by mixing which accompanies the downdraft of rain from the above freezing layer aloft. Heavier intensities of freezing rain tend to turn to rain instead.

Typically, the larger accumulations of freezing rain arise near and parallel to a stationary or very slow moving frontal zone and occur in a band of considerable longitudinal width. Persistence of freezing drizzle also can be responsible for significant accumulations. In the latter cases, the persistent freezing drizzle occurs more frequently in a maritime setting where a sustained flow from an area of ice or water below 0°C has an upslope component of flow.

SUMMARY

In general, techniques to forecast the expected quantity of precipitation are limited. Correlative procedures often do not provide great accuracy, but are commonly applied to the problem anyway. Correlative procedures work better if the forecaster can subjectively adjust amounts for changing physical processes; however, this adjustment is not easy and often incorporates a fair amount of experience and climatology. Extrapolation techniques can prove useful in the very short term, but quickly lose accuracy when synoptic systems change significantly.

One fairly simple technique is to monitor recent weather reports (including use of satellite and radar images) and to translate these reports and their short term expectation into precipitation amounts. By accounting for the number of hours (real and forecast) expected with each intensity of precipitation and by converting the intensities to hourly rates of accumulation, a total amount can be estimated. The conversion to an hourly accumulation can be handled in a 'ballpark' manner through a couple of approaches. The definition of precipitation intensities given in MANOBS can give a crude estimate of accumulations. Sometimes, upstream observations can indicate the accumulation rates corresponding to reported intensities. Alternatively, for winter precipitation, a nomogram such as the one given in Figure 1 can be consulted to relate hourly snowfall accumulations to snow visibilities. The nomogram, which makes use of the wet bulb potential temperature of the precipitating air mass, is not always the most reliable (but better than nothing).

2. FORECASTING PRECIPITATION TYPE

An important part of the winter forecast problem is the determination of precipitation type - rain, snow, freezing rain, or any combination thereof. The user, whether public, aviation, or marine, has a particular interest in the form of winter weather. For the forecaster, this interest extends even further because an inaccurate call of the precipitation type can affect a number of other forecast products. The precipitation type expected has a significant influence on other forecasts of precipitation amounts, maximum and minimum temperatures, ceilings, visibilities, and other aviation hazards.

The meteorological fields that correlate well with precipitation types tend to be thermal. The reason that the thermal Fields work better than other predictors is because the type of precipitation that results at the ground is determined by the thermal structure of the atmosphere within which precipitation is falling. Typically, short term forecasts of the precipitation type are obtained by correlating current and/or past observations of precipitation type boundaries with thermal fields such as thickness and by predicting the short term evolution of the correlated thermal field.

An advantage of using thermal (thickness) fields in the prediction is that these fields tend, in general, to be fairly conservative. If the weather systems are not changing dramatically, these thermal fields often can be extrapolated fairly well. When changes occur, the forecaster must somehow make subjective adjustments for the additional large scale processes at work. Often, precipitation type boundaries can be correlated quite well to surface features which, in turn, can be forecast using short range motion systems techniques. Fronts prove particularly useful for this correlation.

When dealing with current time, tephigrams reveal in detail the thermal structure associated with the different precipitation types. Representative tephigrams can be used with reasonable success for short term forecasting time frames of up to 12 hours. When the representative soundings are subjectively modified for physical processes that are projected to take place, they become even more reliable to the forecaster in predicting precipitation types.

Of the various precipitation type boundaries, the one between freezing precipitation and the other types (rain, snow) is usually the most difficult to forecast. Difficulties arise because freezing precipitation is determined by the detailed thermal structure of the lowest portions of the atmosphere - a part of the atmosphere that can prove difficult to predict because of the variety of boundary layer influences at play.

For freezing precipitation to occur, surface temperatures generally should be at or below freezing while aloft, a layer of air should exist with temperatures near or above freezing. Since the occurrence of freezing rain is very much determined by the low level structure of the atmosphere, critical thicknesses can only satisfy necessary but not sufficient conditions for its occurrence. In practice, freezing precipitation can best be forecast through use of several approaches - critical thicknesses (preferably low level), representative soundings, and correlation with surface synoptic features.