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FTS (Fog To Snow) conversion process During the SNOW-V10 project

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Abstract

The objective of this work is to understand how winter fog which occurred on Whistler Mountain on 3-4 March 2010 developed into a snow event by the means of the FTS (Fog_To_Snow) process. This event was documented using data collected during the Science of Nowcasting Winter Weather for Vancouver 2010 (SNOW-V10) project that was supported by the Fog Remote Sensing and Modeling (FRAM) project. The FTS resulted in a snow event at about 1850 m height where the RND (Roundhouse) meteorological station was located. For both days, there was no large scale system that affected local fog formation and its development into snow. The patchy fog occurred in the early hours of both days and was based below 1500 m. Clear skies at night likely resulted in cooling, the valley temperature (T) was about -1°C in the early morning, and snow was on the ground. Winds were relatively calm (<1 m s^{-1}). At the RND site, T was about -3°C. Weather at RND was clear and sunny till noon. When fog moved over the mountain peak/near RND, light snow started and lasted for about 4-5 hrs and was not detected by precipitation sensors except the Ground Cloud Imaging Probe (GCIP) and Laser Precipitation Sensor (LPM).

In this work, the FTS process is conceptually summarized. Because clear weather conditions over the high mountain tops can become hazardous with low visibilities and significant snow amounts (<1.0 mm hr^{-1}), such events are important and need to be predicted.

1. Introduction

Mountain weather systems change quickly because of various boundary layer processes such as radiative heating, turbulence, lifting over the sloped surfaces. Time and space scales for changes in microphysical, dynamical, and radiative processes over mountain surfaces can be much shorter than those associated with flater terrain. Fog usually forms when relative humidity with respect to water (RHw) reaches to ~100%, and reaching this point can be effected by various conditions e.g. radiative cooling, lifting, turbulence, and evaporative mixing [1].

The objective of this work is to understand how winter fog at low levels (below 1500 m) which occurred on Whistler Mountain on 3-4 March 2010 developed into a snow event by the means of the **FTS** (**F**og_**T**o_**S**now) process that was documented for the first time (Fig. 1). This event occurred during the Science of Nowcasting Winter Weather for Vancouver 2010 (SNOW-V10, [2]) project that was supported by the Fog Remote Sensing and Modelling (FRAM [1]) project. The FTS resulted in a snow event at about 1850 m height where the RND (Roundhouse) meteorological station, with several precipitation and visibility sensors, was located. For both days, there was no large scale system that affected local fog formation and its development into snow.

2. Observations

At the RND site during SNOW-V10, there were several instruments [3;4] measuring visibility, surface precipitation, wind, radiation, and particle type. The deployed sensors are shown in Fig. 1-f that includes Vaisala FD12p, Sentry, Geonor, YES TPS, VRG101, RID, SVI, FMD, GCIP, MRR, 2D and 3D-Yonge, WXT520, HMP45C, OTT-ParSiVel, Biral MRR and LPM, SR50, CRN1, and SPN1. In case of failure of one of the sensors, measurements of important parameters were usually made by more than one instrument.

Figure 1: Pictures taken during the FTS process: a) low level fog at VOL station (early morning), b) elevated fog taken from the RND station, c) increasing cloudiness at RND (early afternoon), d) clear sky conditions at the RND, e) developed stratus/altostratus clouds and fog seen at RND, and f) snowing and cold fog at RND station (late after noon).

The ground imaging probe (GCIP) measurements of particle shapes and sizes from 7.5 micron up to 960 micron over 62 bins (64 diodes) with 15 micron resolution are used for snow/fog particle detection together with a fog device (DMT-FMD). A 7.5 micron particle travelling directly over the diodes' centre in the receiver could meet the 50% shadowing criteria and can be detected. The GCIP instrument is adapted for ground-based applications and is based on a DMT CIP probe which is usually mounted on an aircraft. The heated inlet is used to keep the surfaces clean and primary suction is provided by the two-six inches ports giving a flow rate of 25 m s^{-1} at the measurement area. Three distinct zones of heat control are provided and the entire horn exterior is insulated to reduce thermal losses. The flow cross-sectional diameter varies from 12" at the inlet to 4" between the CIP arms. A VAISALA ceilometer measurement of cloud base height, and T and RHw profiles obtained along Whistler mountain slope are shown in Fig. 2a and 2b, respectively.

3. Analysis and Results

The patchy fog occurred in the early hours of both days and its top height was below 1500 m (Fig. 1a). Figures 1a-f show time development of the FTS process. Clear skies at night likely resulted in radiative cooling, and the valley temperature (T) at VOL station on March 4 (March 3) was about -1°C (+3°C) in the early morning (Fig. 3a), with snow on the ground on both days (Fig. 1). Here, the results from only the March 4 will be summarized. Winds on this day were relatively calm (<1 m/s) and T was about -6°C at 15 UTC at RND. (Fig. 3b). The RHw was 100% before 15 UTC (Fig. 3c). Fig. 3e shows Vis ~100 m at VOL during the fog event. The foggy air at VOL lifted to higher elevations (Fig. 1b) before local noon. Weather at RND was clear and sunny until noon (Fig. 1c). When shortwave (SW) radiation provided additional heat at the low levels and sloping surfaces, the fog started to lift over a 3-4 hr time period gaining additional moisture from melting snow (Fig. 1d). Then, the fog layers were eventually converted to cumulus/altocumulus. In the afternoon, at about 01:30 PM, the entire valley was filled with a fog/cloud mixture (Fig. 1e). Figs. 3d-f show that at RND T was less than 0°C and RHw was ~80%. When the fog moved over the mountain peak/near RND (Fig. 1f), light snow started (0.2 mm h^{-1}; Fig. 3f) with Vis~2-3 km (Fig. 4) and lasted for about 4-5 hrs. Snow was not detected by weighing precipitation sensors (Fig. 3f) except with the Ground Cloud Imaging Probe (GCIP; Fig. 4a) and disdrometers (e.g. Laser Precipitation Sensor (LPM) and OTT (Figs. 3f and 4b, correspondingly).

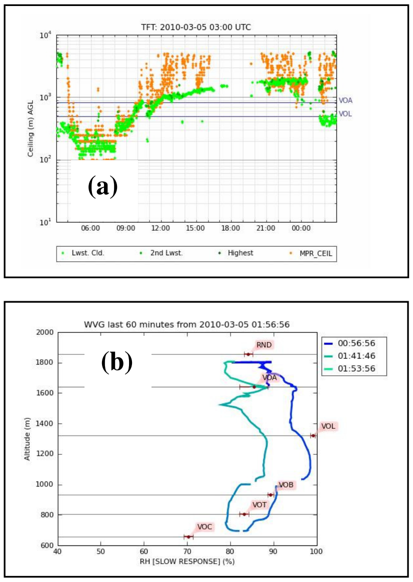
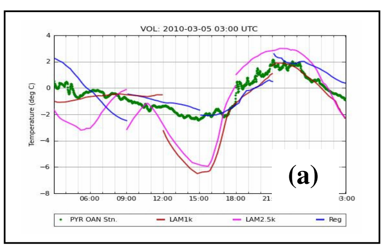


Fig. 2: Times series of fog base height measured at the Whistler Mountain base for March 4: a) green dots represent VAISALA ceilometer and brown dots represent the MPR (Microwave Profiling Radiometer, Radiometrics Inc.), b) profiles of RH measured by the sensors mounted on a Gondola along the Whistler Mountain slope.



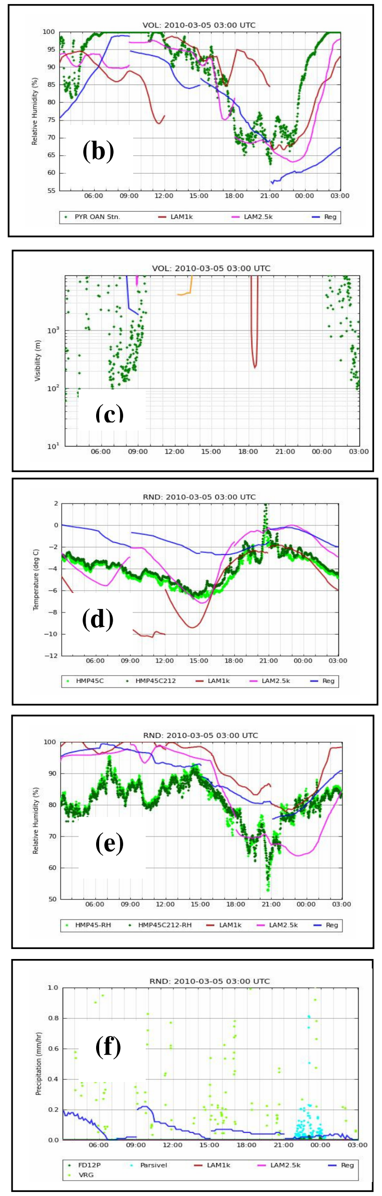


Fig. 3: Time series of T, RHw, and Visibility for VOL station and T, RH, and precipitation rate from FD12P, VRG101, and OTT ParSiVel for RND station. The VRG measurements are an artefact due to wind speed. The colour solid lines are predicted parameters obtained from the Canadian GEM model.

4. Summary and Conclusions

During the FTS process, snow occurred at high elevations but this was not predicted with any model simulation. It was detected by some sensors but most of the sensors missed this precipitation type which occurred as a result of the FTS process.

The following conclusions are obtained from this work:

- Visibility was low at the low levels early in the morning but it became worse during the FTS at high elevations after 3 pm local time.
- Forecast of the FTS process is important to meteorologists because it lowers mountain Vis down to 2-3 km from a clear sky condition and increases snow precipitation rates up to 0.2-0.5 mm h^{-1}; meanwhile its is not predicted by the models.
- Cloud base decreased gradually at the high elevations and it was not detected by the model predictions.
- Solar radiation played an important role over the sloped surfaces by increasing radiative heating at low levels, resulting in a moisture source for high level fog and snow formation.
- GCIP sensor measurements were effective at measuring the light snow amounts e.g. snow particles and its spectra.

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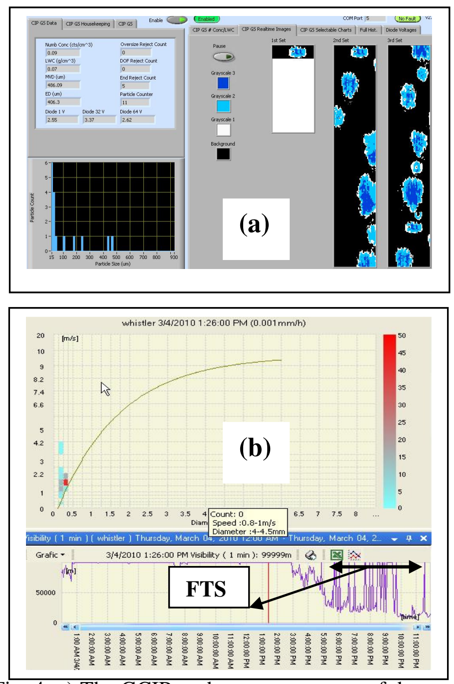

Fig. 4: a) The GCIP probe measurements of the snow particle shape and spectra, and b) LPM measured snow particle counts as a function of particle fall speed and size, and LPM snow visibility (bottom panel).