5.1 **THE ST. PATRICKS DAY SNOWSTORM, 2002, ANCHORAGE, ALASKA**

Joel Curtis, John Papineau, Carven Scott, Weather Forecast Office, Anchorage, Alaska;
Kent Johnson, Meteorological Service of Canada

INTRODUCTION

A quasi-stationary snow-band produced a record 29 inches of snow in less than 24 hours at Anchorage, Alaska on March 17, 2002. What made this storm unique was the intensity and duration of the snowfall as well as the limited spatial extent of the heavy amounts.

Even with the benefit of post-storm analysis it is difficult to completely understand the intense precipitation processes in this record event. Both the synoptic and mesoscale patterns were such that a forecaster would expect subsidence and drying over the Anchorage area. At first glance, the synoptic scale NWP guidance prior to and during the storm gave no indication of snow-band development over Anchorage. Furthermore, high resolution mesoscale model output from the RAMS (4 km) failed to forecast either the location or the amount of snow. A consensus of the model QPF and snow accumulation showed the maxima either over the Gulf of Alaska or along the west side of Cook Inlet and not over Anchorage.

This paper will show the development of the heavy snow in the observations with a diagnosis of the extraordinary local upward vertical motion field that produced this event. It is hoped that broader exposure of this case will encourage dialog between the NWS Anchorage Forecast Office and the research community in order to better understand the precipitation processes that occurred in this record snow event.

INITIAL CONDITIONS

By 00Z on March 17th, 2002 an extremely long, mid and high level southerly fetch of moisture from near Hawaii had set up over South Central Alaska (Fig. 1). The axis of the flow was approximately 150 degrees West Longitude with a 300 hPa jetstream of up to 150 knots. (Fig 2. - Jet) This jet was driven by an extensive upper trough over the Bering Sea and a high amplitude, low wavelength upper ridge over much of the eastern Pacific and eastern Gulf of Alaska. Arctic air was in place over the eastern interior of Alaska under this ridge, and, although somewhat modified, also was in Cook Inlet which extended as far south as Kodiak Island.

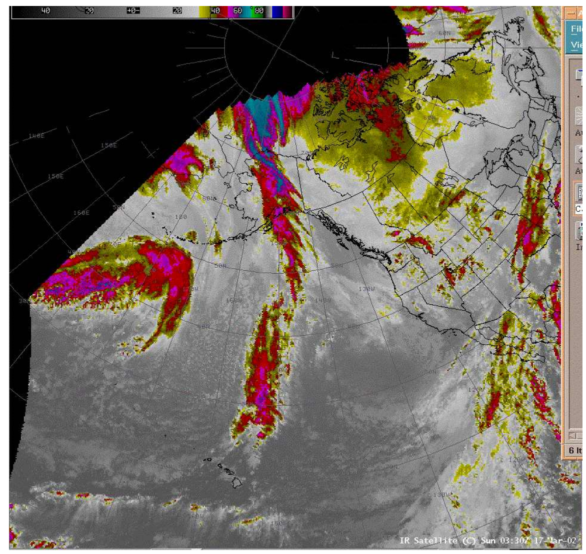

Figure 1. GOES 10 IR 0330 UTC March 17, 2002

Surface analysis revealed a weak wave on a dissipating surface front zone moving northward under the jet in the Gulf. A moderate surface high cell persisted over northwestern Canada with a surface ridge extending over Anchorage. By pattern recognition, Anchorage Forecasters had determined during on both the day and swing shifts on Saturday, March 16th that there was some possibility of snow, but the snow would be mitigated by an ordinary local low-level wind regime of easterly winds gusting to 55 MPH as stated in the Anchorage zone forecast.

3. THE DEVELOPMENT OF HEAVY SNOW-BANDS

The Kenai WSR-88D radar reflectivity showed a typical precipitation pattern at 00Z/17th with snow bands oriented south to north mainly over Cook Inlet with orographic snow falling along the Aleutian and Alaska Ranges. Easterly low-level winds with peak winds speeds 45 to 55 knots were being observed near Anchorage until 05Z even though light snow began to fall at Anchorage International Airport at 02Z, which was followed by

Corresponding author address: Joel Curtis, Weather Service Forecast Office, 6930 Sand Lake Road, Anchorage, Alaska 99502

moderate snow up to 06Z. The 06Z radar reflectivity shows that the snow-bands are becoming more oriented to the southwest-northeast and increasing in intensity. By the peak of the snowfall, which was around 12Z, surface

visibility had dropped to 1/4 mile at Anchorage International Airport, but with no significant cooling in temperature. The upper air observations there showed obvious saturation. The heavy but unusual SW-NE snow-bands that had become stationary over much of Anchorage and the northernmost Kenai Peninsula (Fig. 2), and these persisted until 00Z on the 18th.

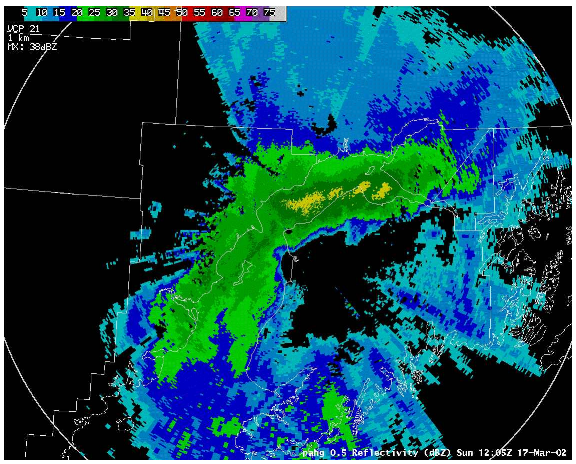

Figure 2. 0.5 degree Reflectivity from the Kenai Radar at 1200 UTC March 17, 2002

The impact of the heavy snow was significant even by Alaskan standards. Snowplowing crews for the roads and runways around Anchorage could not keep anything cleared. The local airports were closed for almost a day for an area that is utterly dependent on air transportation. Yet, when one examines the extent of the heavy snow (Fig 3) , the question must be asked: why was there such an intense snowfall over such a small area and for such a long duration?

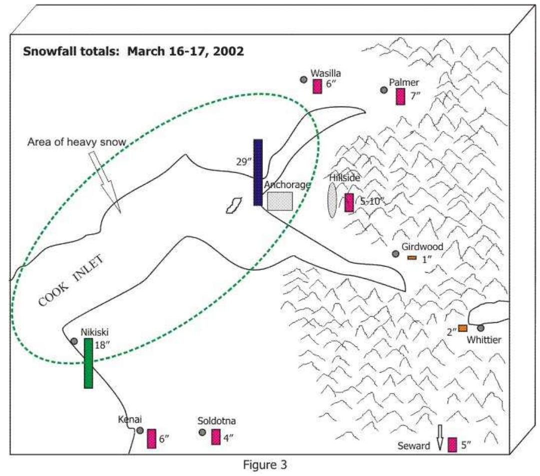

Figure 3. Extent of 24 hour Snowfall Ending at 0000UTC March 18, 2002

DIAGNOSIS OF VERTICAL MOTION

It is worth repeating that experienced Anchorage forecasters would at once expect that any potential for heavy precipitation would be mitigated in this case by the "downslope" easterly low-level winds by subsidence drying. The first key observation concerning the unusual conditions is that the slightly modified arctic air was actually being supported by these low level winds which were from an even colder region. The temperatures at 850 hPa actually cooled by 12Z (Fig. 4). This cold air advection is contrary to the usual adiabatic warming that occurs for Anchorage in this wind regime although strangely, the winds were veering with height. The snowfall also cooled the air column. Essentially, Cook Inlet was filled with cold air which made the area "effective terrain" for no downslope warming from any direction including the southerly flow aloft.

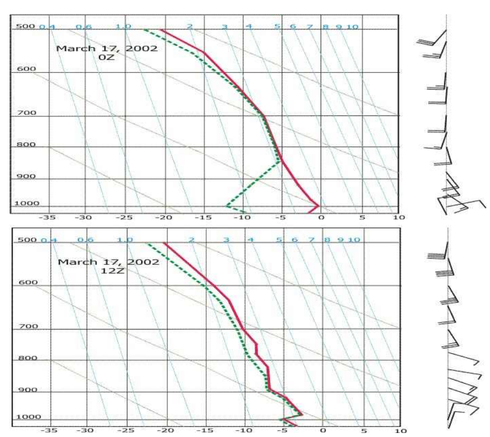

Figure 4. Anchorage RAOBS 0000 UTC and 1200 UTC 17 March, 2002

Certainly, there was plenty of available moisture from the tropics and this was aloft (Fig. 1). An exploration of synoptic scale vertical motion as revealed by the 48 km eta convergence of Q at 700 hPa led to an expected result: not much QG forcing was produced in this model at a typical level. When one considers higher levels such as 500 hPa, this is usually too high for significant precipitation processes in the Anchorage forecast area, especially when considering a low “level of non- divergence” in a northern area where the tropopause is naturally low. However, upon examination of the convergence of Q at 500 hPa, it turns out that the 48 km eta shows strong convergence of Q at 500 hPa throughout the snowstorm (Fig. 5). This supports the idea that the upward vertical motion was higher than usual in the atmosphere, and that the 48 km eta model captured this upward vertical motion over South Central Alaska in general on the 00Z/17 and 12Z/17 runs. The model QPFs, however, using a 10 to 1 snow to water ratio indicated around 10 inches of snow, but specifically in the wrong place, which, of course, was critical to the forecast. Frequently, forecasters at the Anchorage WFO will see model forecasts of 10 inches over the mountains that are completely remote and uninhabited and usually such a big number as 10 inches is not included in the forecast text as representative of the populated area.

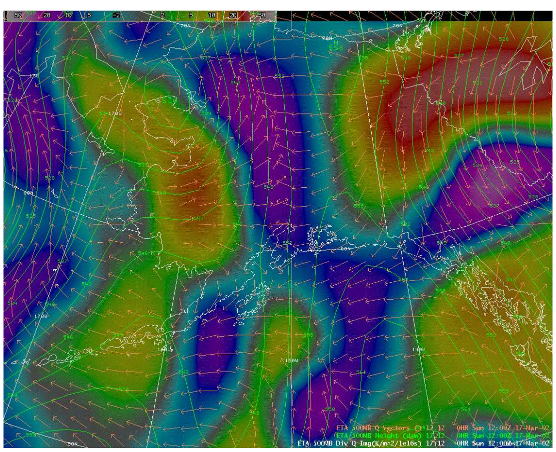

Figure 5. 48km Eta Convergence of Q at 500 hPa 1200 UTC March 17, 2002

A further search for the vertical motion leads one to conduct vertical cross sections in the data to better understand the processes. Unfortunately, due to the sparsity of actual observations, these cross sections must be conducted through available model generated fields. Due to the general success of the 48 km eta in the diagnosis of QG forcing described above, the investigators decided to try cross sections using the eta both along and through the upper flow. The sections along the flow proved most enlightening when considering the actual terrain combined with the “effective terrain”.

The 48 km eta model has ample moisture as was observed which is evident in both the equivalent potential temperature and relative humidity fields (Fig. 6) which is shown here during the most intense period of the snowstorm (12Z). A secondary maximum of omega at higher levels, above 700 hPa, is evident at the latitude of Anchorage which fits in well with the QG evidence presented so far. The gradual slope of the equivalent potential temperature isotherms is indicative of gradual assent of moist air from the Gulf and further south.

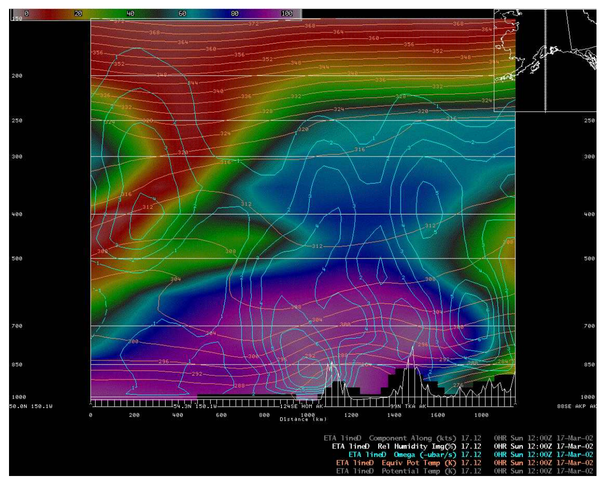

Figure 6. South to North Cross-Section of the 48 km Eta Across Anchorage, Alaska at 1200 UTC March 17, 2002

One possibility worth exploring is mountain wave enhancement from the southerly flow off the Gulf of Alaska encountering the southern Kenai Mountains. Detailed Polar Orbiter IR Satellite imagery shows a cold cloud that is located in a favorable position for a mountain wave to enhance the upward vertical motion, but the orientation of this terrain feature appears to not be ideal for a significant mountain wave.

CONCLUSIONS AND THE NEED FOR FURTHER STUDY

The authors realize that the above diagnosis is speculative, but the evidence, much of which is in the 48 km eta model, is mutually supportive and plausible. Without any evidence of lower level processes, it is reasonable to assume that the upward vertical motion took place aloft, beginning above 700 hPa. This also fits in well with Cook Inlet as having “effective terrain” , as a concept of the near sea-level area being “paved over” by cold, dense, and increasingly moist air. The duration of the snowstorm can be explained by the steady state of the high-level flow, both in speed and direction through 00Z on the 18th. This, too, is mutually supported by the continuing steam of moisture from the tropics. The downslope mitigation of precipitation that the forecasters are so used to seeing was actually cold air advection supporting the “effective terrain”.

One must consider the gradual ascent of the air from the Gulf over the cold air in Cook Inlet. It is possible that a mountain wave could have enhanced the upward vertical motion in the limited area of heavy snow, but the gradual lift from the South is a more likely supporting process.

This record snowfall case is unique for many reasons mentioned above. It is hoped that the research community will continue to have an active interest in this event, and all forecasters and researchers alike are encouraged to recommend ideas as to the causes and processes that occurred in this storm.