# 11.8 OROGRAPHIC EFFECTS ON COASTAL CYCLOGENESIS IN NEW ENGLAND

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## 1. INTRODUCTION

The Appalachian Mountains' proximity to the East Coast has long been thought to have an effect on the processes of winter weather (Miller, 1946). Miller attributed the topography of the North American East Coast to the U-shaped surface pressure isobars, coastal front formation, and occlusion of his Type-B cyclone. He also considered the East Coast to be a great place for rapid cyclogenesis and cyclonic intensification. There are many processes that occur with winter weather storms on the East Coast, many of which occur at or near the surface. These include processes such as cold-air damming (Bosart et al.,1972, Bell and Bosart, 1988, Kocin and Uccellini, 2004a), coastal frontogensis (Bosart et al., 1972, Ballentine, 1980, Garner, 1998, Miller, 1946, Kocin and Uccellini, 2004a), and cyclonic development and intensification (Miller, 1946, Maglaras et al., 1995, Kocin and Uccellini, 2004a).

Understanding the processes of winter weather formation is vital to making accurate and dependable weather forecasts. In the past, models had a difficult time predicting these processes (Bell and Bosart, 1988, Kocin and Ucellini, 2004a). These models had poorer resolution and could not efficiently deal with important factors such as the planetary boundary layer and topography. As a result, the temperature predictions were too high along the East Coast making snow prediction difficult (Kocin and Ucellini, 2004a). As resolution and physical features became more easily dealt with by the models, research and forecasts have been able to improve (Kocin and Ucellini, 2004a).

The questions that this research hopes to shine some light on are : What is the effect of the mountains? Do the mountains really cause an increase in stable air along the coast? Are mountains at all responsible for coastal frontogenesis? Do the mountains have an effect on the track a storm will take? Understanding the effects of the mountains will help forecasters to better understand and predict winter storm systems along the East Coast.

## 2. EXPERIMENTAL DESIGN

This research explores the influence of the mountains by taking the mountains out of a numerical weather model. In this experiment, we have used the fifth generation of the Penn State University/National Center of Atmospheric Research Mesoscale Model, version 3 (MM5). A two nest grid has been employed for this experiment. The grid was centered at 42.0ºN latitude and 70.0 º W longitude. The outer domain has 66 grid points in the east-west (x) direction and 54 grid points in the north-south (y) direction. There are 60km between each grid point. Ten minute global terrain and land use data is utilized for this domain. This domain covers the eastern half of the United States, some of southern Canada, and a little part of the western Atlantic Ocean. The inner domain begins at the fourteenth point in the x-direction and the fifteenth point in the y-direction of the outer domain. This grid has 82 grid points in the east-west (x) direction and 73 grid points in the north-south (y) direction with spacing of 20km. Five minute global terrain and land use data is used for this domain. Two-way feedback is enabled to allow the grids to interact completely. Figure 1 shows the domains.

Higher resolution runs were also done to confirm that the large scale patterns would be the same. One experiment was done with 30km grid spacing of the outer domain and 10km spacing of the inner domain. Another run was done with higher vertical resolution, giving double the resolution in the lower atmosphere. In both cases, the sea level pressure pattern came out to be nearly identical.

Two Nor'easters were selected for this study: January 19 – 21, 1978, and February 5-7, 1978. Both of these storms set 24 hour snowfall records in Boston, MA. The January storm was a type A storm, coming from the Gulf of Mexico and tracking up the East Coast, while the February storm was a type B (Miller, 1946), redeveloping along the coast, as the primary storm from the Midwest stayed to the west of the Appalachian Mountains.

For each case, the MM5 was run for 96 hours, starting 48 hours before the storms reached coastal New England. North American Regional Reanalysis data was used for initialization and boundary conditions. Each case was run once with the normal terrain in place (with mountains), and then a second time with the terrain in the model reduced to near sea level (without mountains). Figure 2 uses potential temperatures to show that the initial conditions were essentially an interpolation of the near sea-level data at the same latitude. Figure 3 shows that the upper air flow patterns, including vertical motion, were undisturbed as well.

## 3. RESULTS

The results show the effect that the Appalachian Mountains have on cold-air damming by inspecting the sea-level pressure isobars and temperatures. Coastal fronts are examined by plotting the frontogenesis. The speed of cyclonic propagation is examined by comparing the location of the sea level pressure cyclone at a specific time.

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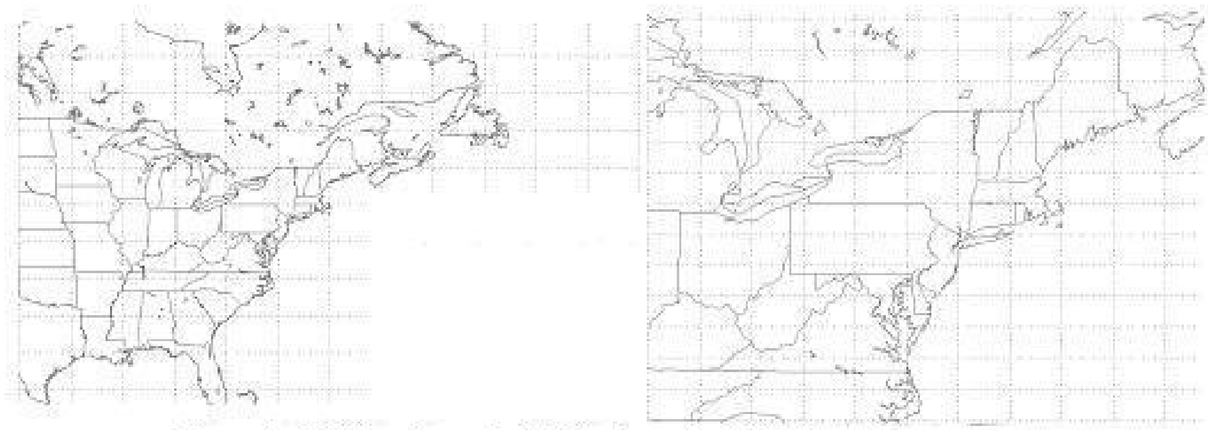

Figure 1 - Grid domains used. Left is outer grid, right is inner grid

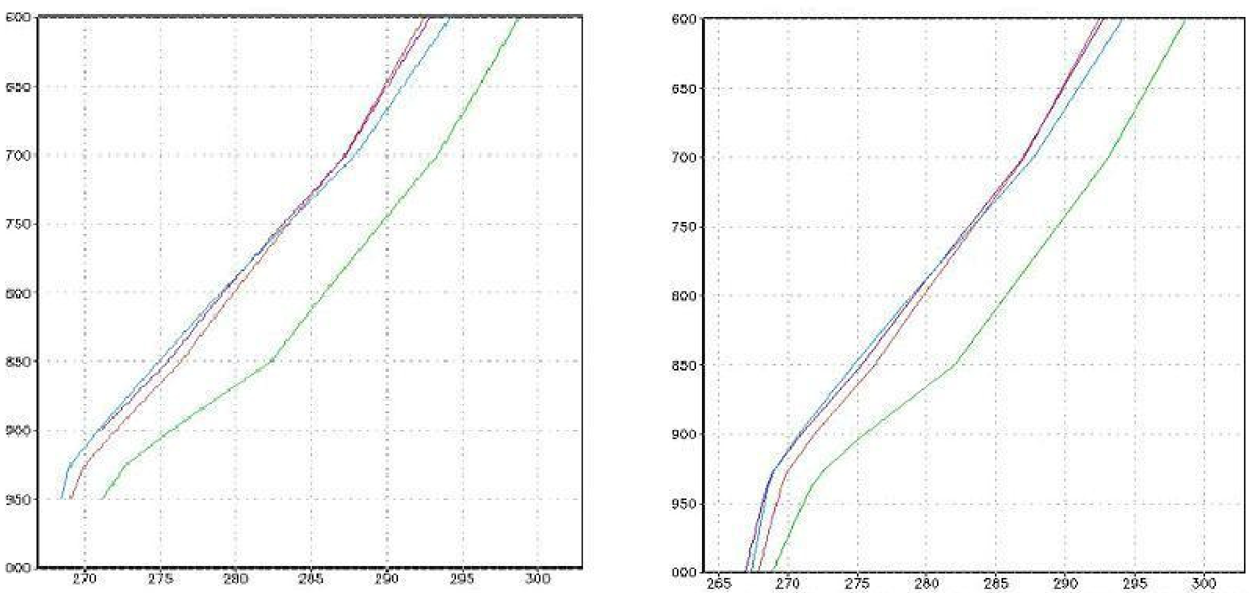

Figure 2 - Potential Temperature (K) Profiles at 38ºN and 92ºW(green), 82.5ºW(red), 80.5ºW (purple), and 78ºW (blue). Left is run with mountains, right is run without mountains

### 3.1 COLD-AIR DAMMING

The January case shows that the elevated terrain plays a role in affecting the pattern of the sea-level pressure isobars. Figure 4 shows a clear difference in the pressure pattern. The image on the right shows that there is a inverted ridge present at 12Z on January 19, but this feature is absent in the image to the left where the mountains are not present. This makes it clear that the mountains have an effect on the inverted ridge associated with cold air damming.

The February case shows a similar occurrence. As the storm begins to form and move up the coast, the sea level pressure pattern changes. The inverted ridge was present at the beginning of the February run for both the case with and without mountains. By 12Z on February 5, the inverted ridge is weak and smoothed on the run without mountains. Contrastingly, the ridge is still present and strong on the run with mountains.

Figure 5 shows the sea level pressure isobars from this time period. The anticyclone from the north is still affecting the sea level pressure pattern, but the effect is amplified by the blocking that the mountains provide.

As the storm moves up the coast, warm air advection pushes the cold dome out of the area. Cold air is held in place in New England by the mountains to the north, preventing cold air recession from occurring. Figure 6 shows that in the absence of elevated terrain in New England, warm advection is able to push the cold temperatures out of the area. For the January case, the temperature difference is greatest in Eastern Massachusetts and southern New Hampshire with a 5ºC-6ºC difference between the run without mountains and the run with mountains. At 6Z on February 7, the temperature difference is greatest in Northern New Jersey with approximately 7ºC of temperature difference. The difference extends into southern New England and increases in New England as the storm moves up the coast. The mountains play a very significant role in keeping the temperatures cold in the northeast during a nor'easter. With temperature differences this great, a large amount of the precipitation would have been rain.

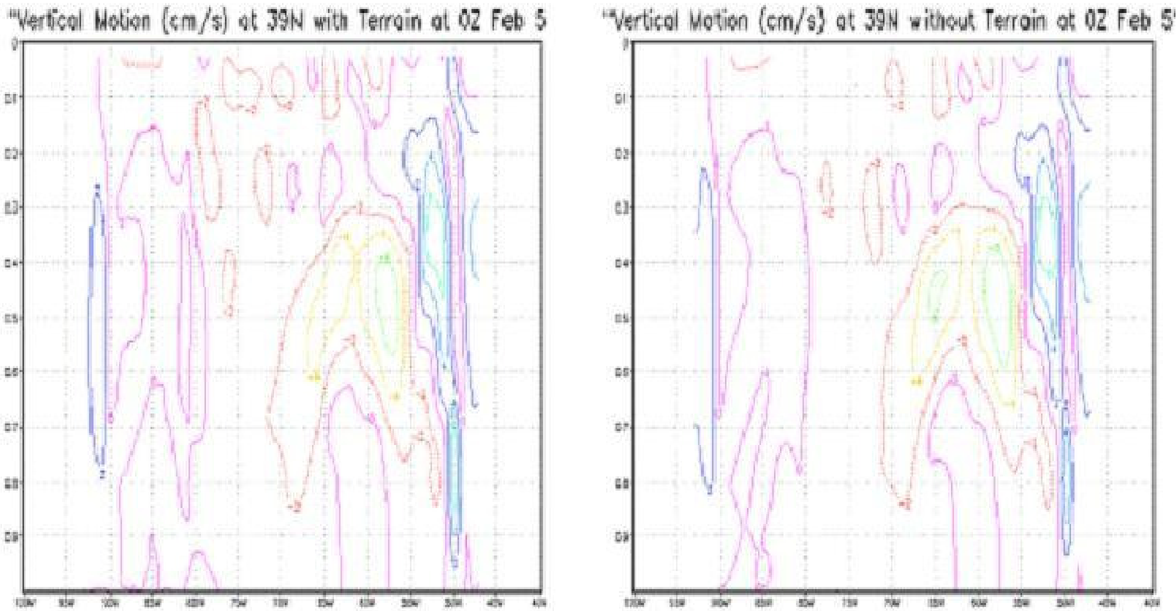


Figure 3 - Cross-sections of upward motion (cm/s) at 39ºN. The left is the run with mountains and the right is without mountains

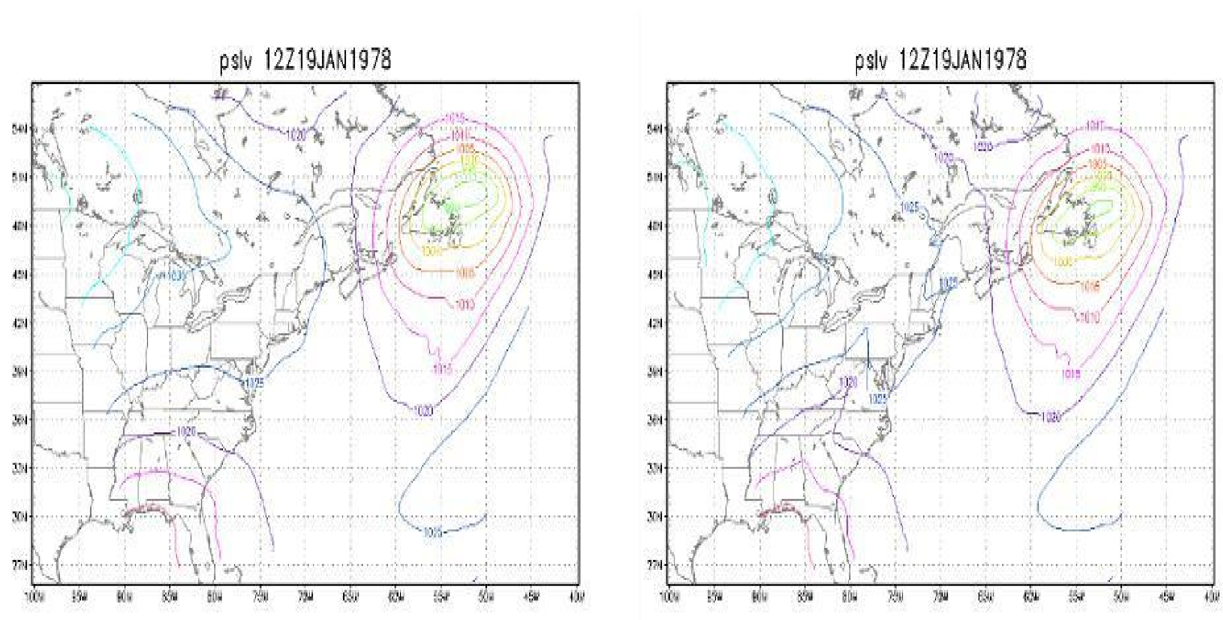


Figure 4 - Sea Level pressure at 12Z on January 19, 1978. The image on the left is from the run without mountains and the image on the right is with mountains

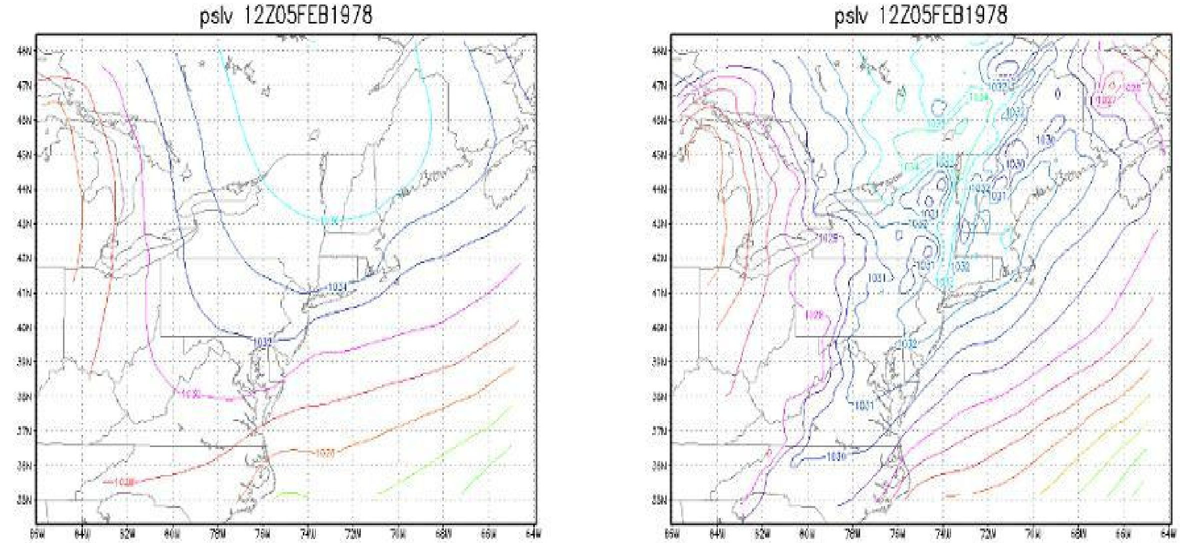


Figure 5 - Sea Level pressure at 12Z on February 5 , 1978. The image on the left is from the run without mountains and the image on the right is with mountains

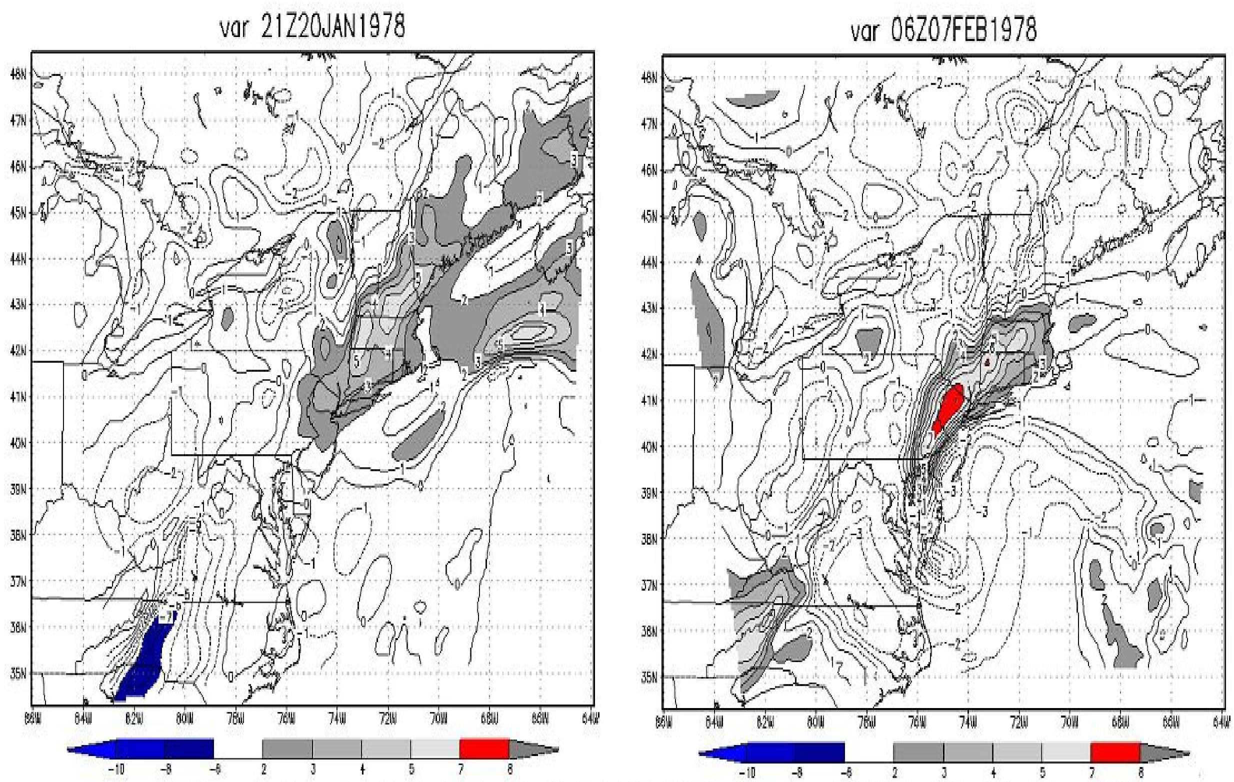


Figure 6 - Difference plot of temperatures (No Mountain Run - Mountain Run). On the left is from 21Z on January 20, 1978, the right is at 6Z on February 7, 1978

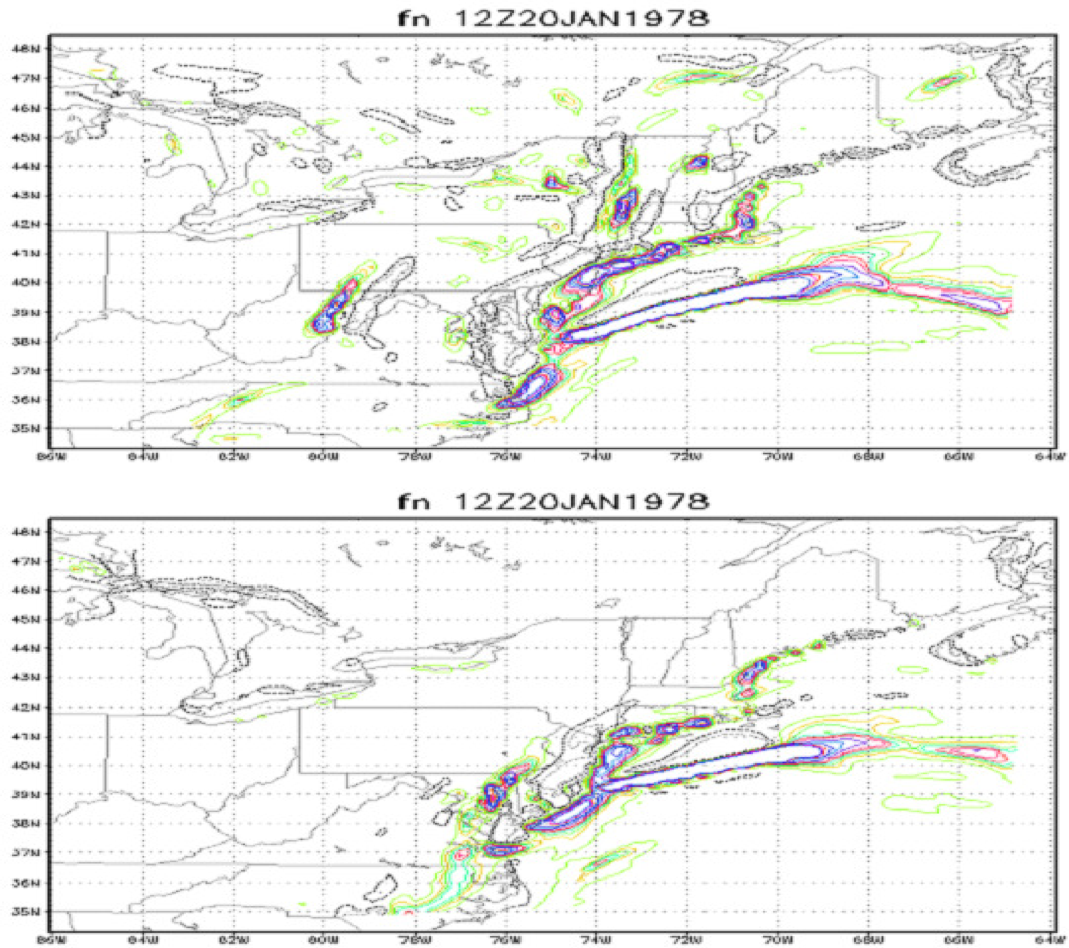


Figure 7 - Frontogenesis at 12Z on January 20, 1978. Top is with mountains; bottom is without mountains.

### 3.2 COASTAL FRONTS

Coastal fronts often form in baroclinic zones where nor'easters are propagating northward along the coast. These coastal fronts can be observed along the East Coast of the United States. The January 1978 case is an example of coastal front formation (Kocin and Uccellini 2004b). Coastal frontogenesis is observed in the run with mountains and without mountains in the same shape and location. Figure 7 shows a comparison of the two runs. At 12Z on January 20, the coastal frontogenesis patterns are nearly identical. Frontogenesis can be observed on the coast of New Jersey, southern New England, and some in northern New England. Over land, frontogenesis is occurring in the area of the mountains on the run where mountains are present, but no frontogenesis is occurring over land on the run without mountains. The elevated terrain of the Appalachian Mountains is more influential on fronts over land than fronts along the coast. Coastal fronts are more likely influenced by other processes such as differential friction (Bosart 1972).

### 3.3 CYCLONIC PROPAGATION

The January case is a Miller type A cyclone that began forming in the Gulf of Mexico, crossed over Florida, and tracked northward up the East Coast. Comparing the sea level pressures of the run with mountains and the run with no mountains, it is clear that the cyclone is able to move up the coast more quickly when mountains are not present. Figure 8 shows that the pressures are lower further to the north in the run with no mountains on January 20, 1978.

The February case is a Miller type B cyclone and redevelopment off the coast is involved. The storm began as a cyclone over the northern plains and was blocked by the mountains and inverted ridge in the Appalachian Mountain region. On the run with no mountains, the cyclone was still blocked by the inverted ridge because the high pressure to the north was strong enough to affect the eastern half of the US. When the storm started to redevelop off the coast, the redevelopment occurred off the southeastern coast at the same time in both runs. Figure 9 shows where the redevelopment occurred for both runs.

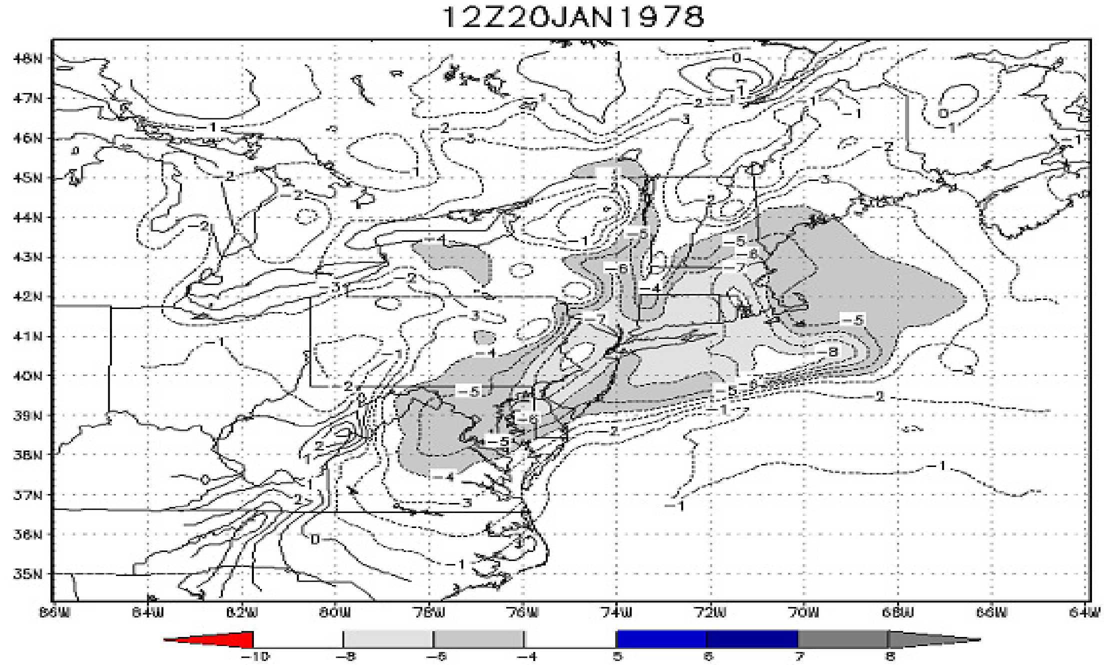


Figure 8 - Sea-level pressure difference. Shaded indicates where SLP is lower on the no mountain run

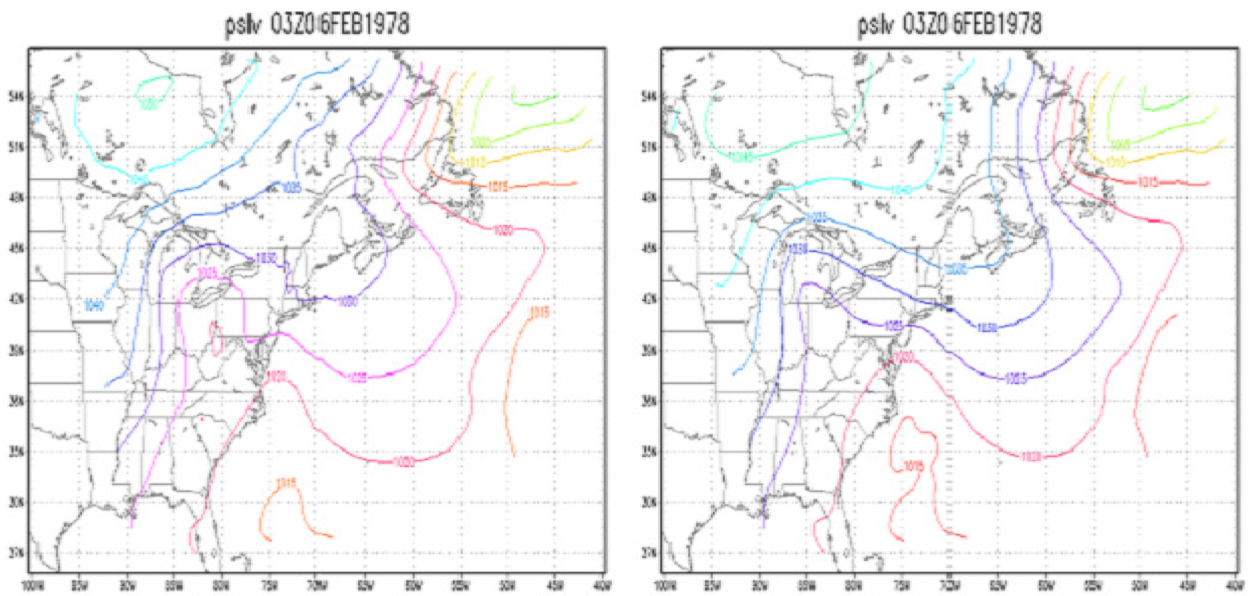


Figure 9 - Comparison of sea-level pressures (mb) during coastal redevelopment on February 6, 1978.
'he run with mountains is on the left, the run without moutnains is on the right.

After redevelopment, the storm began to track up the coast. Figure 10 shows the difference between the sea level pressures for the run with mountains and the run without mountains. Once again, the storm is able to track further north on the run without mountains. In this case, the storm is also able to track more inland.

The slowing of the cyclone propagation as it moves up the coast is likely due to cold air damming blocking the cyclone's movement. The influence of high pressure to the north is more easily pushed away by the cyclone in the run with no mountains because the mountains are not there to block the movement of the high pressure. Because the blocking influence of the high pressure is easily pushed out of the way, the storm is able to move more rapidly up the coast.

## 4. SUMMARY AND CONCLUSIONS

The Appalachian Mountains play an important role in some of the surface processes associated with winter time cyclones that affect the northeastern United States. There is an effect on the cold air damming between the

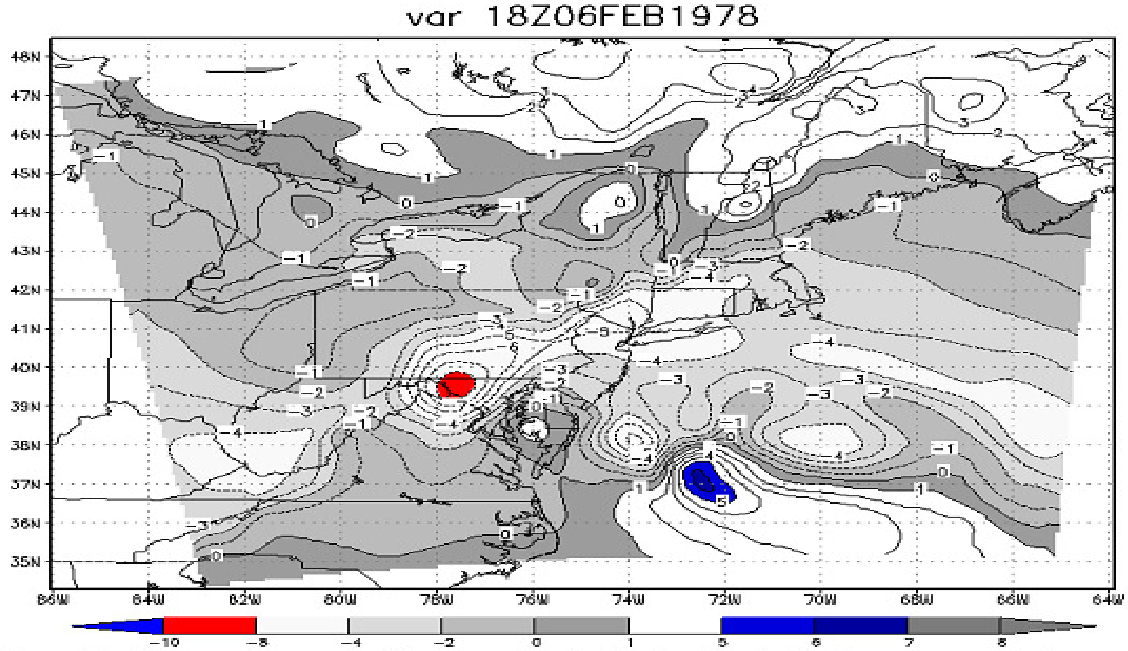


Figure 10 - Sea Level Pressure difference. Shaded and red indicate where pressure is lower on the run with no mountains

mountain region and the coast as well as the cold air recession to the north. The mountains likely play a role in the type of precipitation that is observed during a storm, especially if the temperatures are close to freezing. The cold air damming has an effect on the speed that a cyclone propagates up the coast as well. The mountains have very little effect on coastal fronts.

Future research could include looking at other surface or upper level processes. Another topic could be to increase the height of the terrain and see if the mountains have a greater effect on cyclones. A different process to explore could be determining the role of the mountains and cold air damming pattern during warm months, especially during a tropical to extratropical cyclonic transition. A final topic for research could be to change other processes in the model, such as winds, surface fluxes, etc to see how those mechanisms are influenced by the mountains.

## 5. REFERENCES


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