The 12 November 2003 Los Angeles Hailstorm

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1. Introduction

On 12 November 2003, a powerful yet spatially compact hail producing storm formed, and then remained quasi-stationary, over South Central LA, just east of Los Angeles International Airport (LAX). Precipitation totals exceeding 5 inches, along with pea-size hail drifting to several feet, were recorded in an area encompassing just a few square kilometers while gages located just a few kilometers away showed modest, if any, accumulations (Table 1). The daily operational MM5 run at UCLA captured the development and rough location of this storm, despite rather coarse (6 km) resolution and economical microphysics being employed. The forcing mechanisms for storm genesis and (lack of) movement are examined using still higher resolution simulations, mainly employing more sophisticated physics. These simulations are not always better than the operational run; indeed, some are much worse. At this writing, preliminary runs have also been made with the newly released version 2 of the WRF model.

Gage	Precip. (mm)
96th/Central	136.1
Ducommon St.	18.0
LA River	6.9
LA City Coll.	3.1
Dominguez	3.1
Ballona Ck.	1.5
La Mirada	1.5

2. Background

On the afternoon of the 12th, a cut-off low that had been present over the Southern California Bight migrated eastward over the Los Angeles basin, bringing moist, unstable air from the south and southwest. Meanwhile, light rain had been recorded earlier in the day in the mountains east of LA, and also out in the Mojave Desert to the northeast. Colder temperatures in this high elevation desert contributed to offshore flow, a common occurrence during the winter season. Light rain began falling at the tipping bucket gage at 96th and Central, in South Central LA, around 2227Z (14:27 Local Time). Heavy rain started there around 2330Z and persisted for just over 2.5 hours. The largest rain rate noted during this period was 174 mm h^{-1}, at 0103Z on the 13th. By the time rain finally ceased at 0403Z (20:03 local), the gauge had recorded 136 mm (Table 1). Copious hail also fell in this general area, with an unknown effect on the precipitation collector. Noticeable amounts of hail were still present in the area two days later.

In the hours prior to the development of the hailstorm, radar revealed scattered echoes moving generally from the south over West LA and and the adjacent ocean. A sequence of relatively bright but short-lived echoes formed in this area, several kilometers west of where the hailstorm subsequently appeared, but these produced only light rain. The hailstorm could have formed on the southeast flank of these cells as the latter dissipated and moved north towards the mountains. Figure 1 shows the 0105Z radar image from the Santa Ana radar, around the time of the maximum recorded rainfall. An observer located to the east of the hailstorm (P. Magallanes, pers. comm.) reported seeing a line of "feeder cumuli" arrayed to the south, consisting of cells merging in with the main storm. He reported that this configuration persisted with little change for over two hours.

3. Operational MM5 run

The MM5 model is run real-time at UCLA for research and educational purposes. The model has 23 vertical levels and is triply nested with 6 km resolution in a domain straddling the LA area. Simple ice microphysics is employed along with the Kain-Fritsch 2 cumulus parameterization in the two coarser

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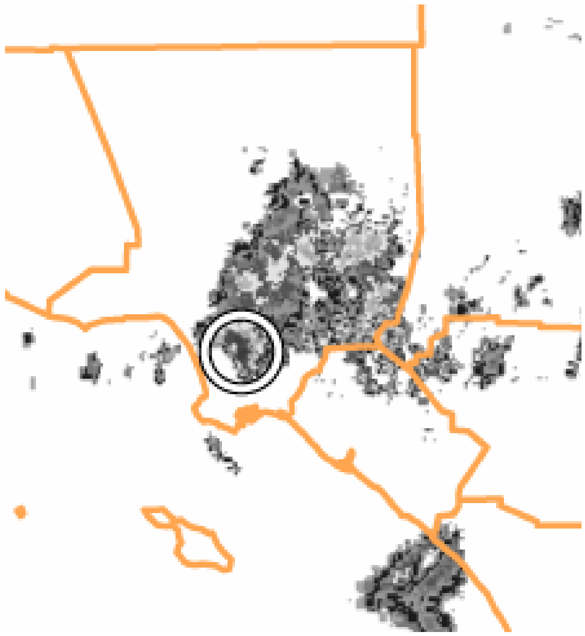

Fig. 1: KSOX radar image for 0105Z 13 Nov 2003. The circled echo was by far the brightest on the image.

meshes. Initial and boundary conditions are provided by the 40 km Eta gridded product, and integration commenced from a cold start at 12Z (0400 local).

Precipitation accumulations in the operational run's 6 km domain are shown in Fig. 2. A prominent bulls-eye in rain rate is seen in the LA basin, south and west of the mountains that surround the area. Compared to the observations, the maximum precipitation is underpredicted (by 41%) and located too far to the east. In the model, rain started after 0100Z (1700 local), later than observed, in the foothills south of Pasadena. Precipitation increased through 0500Z as the convection migrated slowly to the southwest, closer to where the actual storm became anchored. As rainfall waned thereafter, the precipitation center retreated eastward. Despite position and timing discrepancies, this forecast is judged to be fair to good, particularly considering how rare storms of this magnitude and compactness are over the lower elevation portions of the LA basin.

4. Higher resolution MM5 runs

Encouraged by the success of the operational run, higher resolution simulations of this case were attempted. Four telescoping, two-way nests were used, with the finest (1 km) mesh placed over the lower elevation section of the LA basin. The best simulation generated thusfar employed Reisner 2 microphysics without any cumulus parameterization, even in the 27 km outermost domain. The precipitation accumulation from this simulation is shown in Fig. 3. Rainfall is still underestimated, and the model did not predict any precipitating ice at the ground[1]. However, there is a precipitation maximum much closer to the location where the actual hailstorm became stationary. The radar estimated storm total rainfall through 0415Z is shown for a roughly similar area in Fig. 4. The observed and predicted patterns bear some resemblance.

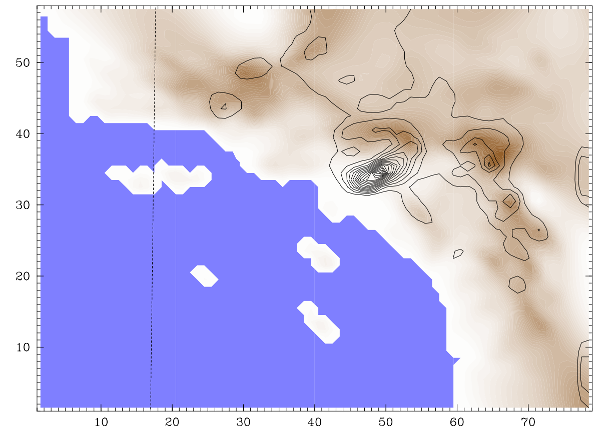

Fig. 2: Precipitation accumulation in 6 km domain in the operational MM5 run. Maximum value: 80 mm. Topography field shaded.

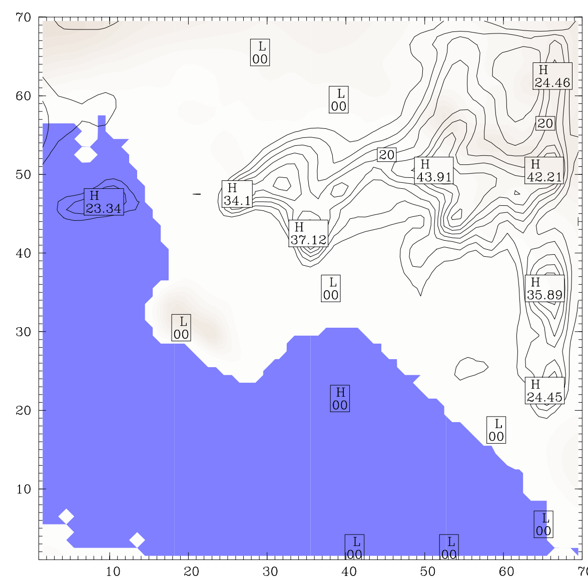

Fig. 3: Precipitation accumulation in the 1 km domain of a four-nest run employing Reisner 2 microphysics.

[1] An ARPS cloud model storm made with a sounding extracted from this MM5 run was a very prodigious hail producer. That simulation employed microphysical alterations discussed in Wakimoto et al. (2004)

This higher resolution model simulation appears to have created a precipitating storm in the LA basin for a different reason than the operational run. In this simulation, precipitating convection cropped up near the Puente Hills (see the northeast quadrant of Fig. 5) around 2300Z (1500 local), possibly the result of the outflow from an earlier and weak storm located farther to the east. The more substantial outflow from this storm subsequently spread westward, reaching the South Central area by 0130Z. Convection was initiated along this boundary shortly thereafter. However, though the outflow continued to propagate, the convection remained essentially stationary over the region of initiation. Figure 5 displays the situation at 0230Z; the clearly visible cold outflow is clearly has reached the coastline west of the principal model convection by this time.

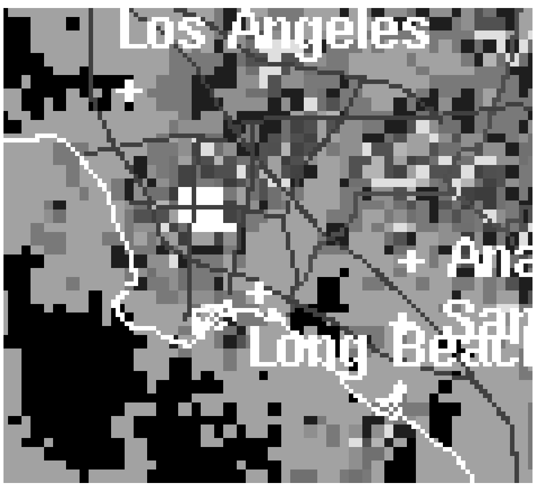

Fig. 4: Radar estimated storm total rainfall from the KSOX radar by 0415Z. Precipitation exceeded 5 inches in white area.

Convection occurred in this simulation as relative high CAPE (up to $\approx$ 1000 J) air washed in from the west and south and collided with this spreading outflow. Figures 6 and 7 track the CAPE field as it approached the Puente Hills. Convection was initiated over those hills at the latter time. The outflow from that convection pushed the high CAPE air back towards South Central, as seen in Fig. 8. As in the operational run, the South Central convection was unrealistically late, only appearing during dusk; at this time, the actual storm was already declining in strength. This probably had a deleterious impact at least on simulated storm strength since the inflowing air's CAPE declined rapidly as the lower troposphere cooled after sunset. As it is, however, the model storm was also able to remain essentially stationary for 2-2.5 hours after initiation.

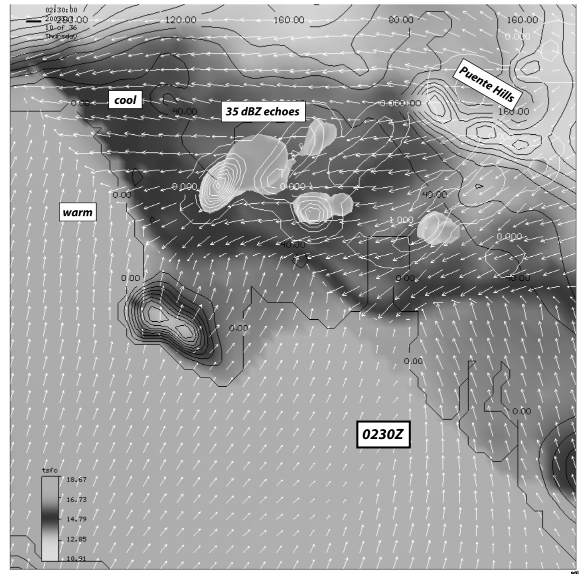

Fig. 5: View of 1 km domain at 0230Z. White contours: last 15 min precipitation accumulation; black contours: terrain.

Why did the model develop convection in the west LA area so late? If the actual storm was also triggered by previous convection in the eastern portion of the basin, it is likely that activity was also delayed in the model. As mentioned earlier, there was precipitation to the east and northeast earlier in the day, and a station at Whittier – located just west of the Puente Hills, 24 km east of the 96th St. gage – recorded the passage of a front-like feature around 2100Z (1300 local; see Fig. 9). In the model, the mesoscale cold front seen on Fig. 5 did not pass Whittier until about 0000Z, three hours too late.

Further, the high CAPE air did not progress towards the LA area until after 1830Z (1030 local), when the previously strong offshore flow began to abate. The model's offshore flow may have been too strong or started weakening too late, or perhaps the cut-off low's movement into the area was too slow. It is possible that the early afternoon convection in West LA accelerated or augmented the hailstorm; that was completely missing in the MM5 simulations.

When this high resolution simulation was rerun without domain #4, no precipitation occurred over the South Central area at all. Without the 1 km nest, the Puente Hills cannot be resolved, and the early afternoon convection made its appearance farther to the east. When the high CAPE air entered into the basin, it flowed without impediment up against the San Gabriel mountains to the north instead of becoming lifted over South Central. An otherwise

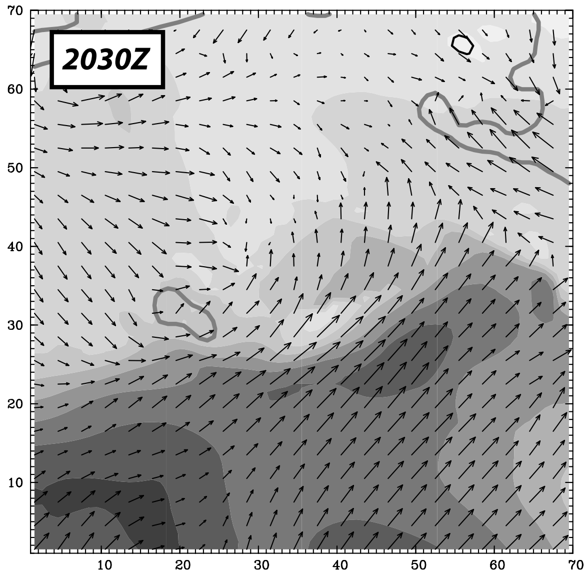

Fig. 6: CAPE (shading interval 100 J) distribution at 2030Z. Black contours show vertically integrated non-precipitating water (2 mm contours).

identical simulation that employed the less sophisticated simple ice microphysics used in the operational run also managed to generate precipitation almost everywhere except in South Central. Again, the bulk of the rainfall occurred on the slopes of the San Gabriel mountains.

5. WRF simulations

Simulations of this case using WRF will be presented at the meeting. Preliminary runs with the recently released model version (V2) differ markedly from the MM5 results, with WRF generating much more widespread convection across the basin, at least in single nest simulations with horizontal grid spacings of 3 and 6 km.

6. References

Wakimoto, R. M., H. V. Murphey, R. G. Fovell, and W.-C. Lee, 2004: Mantle echoes associated with deep convection: Observations and numerical simulations. *Mon. Wea. Rev.*, , in press.

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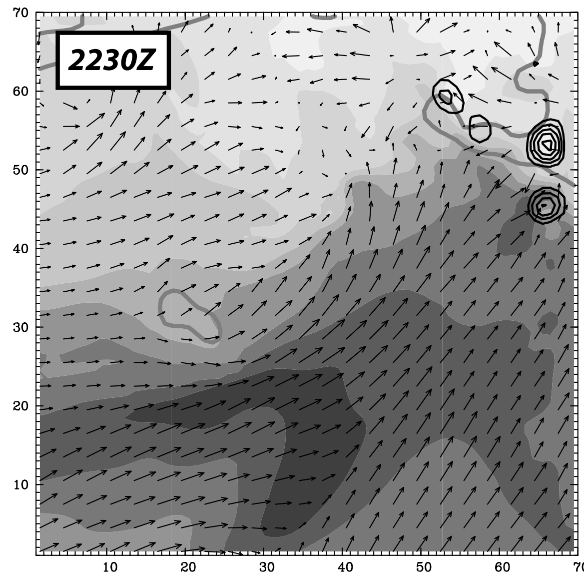

Fig. 7: As Fig. 6, but for 2230Z.

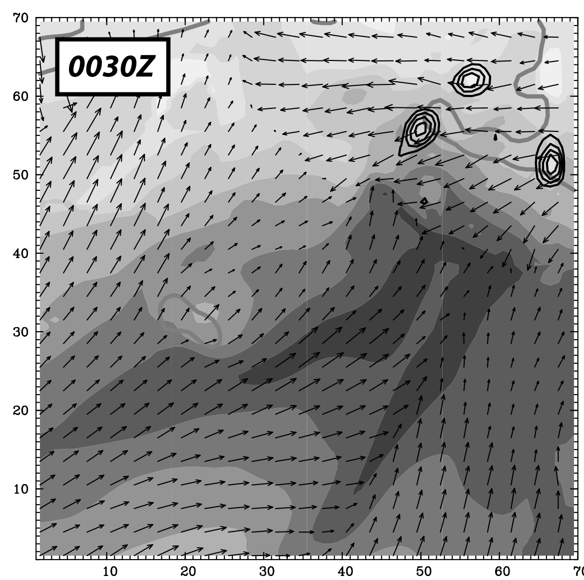

Fig. 8: As Fig. 6, but for 0030Z the next day.

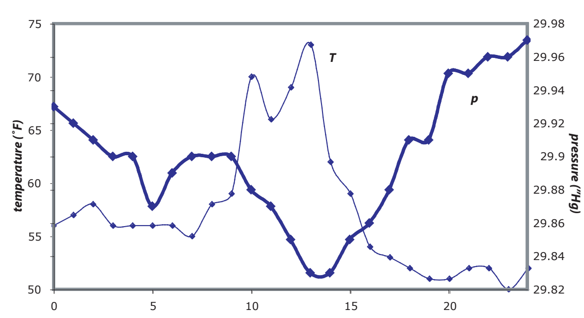

Fig. 9: Time series of temperature and pressure at Whittier, located east of South Central.