15.5 MM5 SIMULATIONS OF DIURNAL WINDS AND MOISTURE TRANSPORT IN THE MT. EVEREST AREA OF THE NEPAL HIMALAYAS: SOME INITIAL FINDINGS

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1. INTRODUCTION

The Mt. Everest area presents both unique and extreme meteorological conditions and remains an almost insurmountable challenge to weather forecasters. The mountain-valley circulation system in the Nepal Himalayas has been well documented and is characterized by vigorous daytime up-valley flows (Barry, 1992) and much slower drainage nighttime winds; the cause for this asymmetry between day and nighttime flows has been the subject of considerable research (Ohata et al., 1981; Egger et al., 2000). Thunderstorms occurred on and near Everest on May 10 and 11; both storms are associated with the 1996 infamous, climbing disaster.

As part of an ongoing study of the relationship between daytime valley winds, moisture transport and thunderstorm initiation (Banta, 1990) at elevations above 3500m asl in the Mt. Everest area of the Nepal Himalayas (Rosoff et al., 1998; Rosoff et al., 2000) a first MM5 simulation was performed. This exploratory, low 3km resolution, run of the NCAR/ Penn. State MM5 Mesoscale model investigated further the diurnal mountain-valley wind circulation in the Mt. Everest area of the Nepal Himalayas, yielding 60 hours of ½ hourly simulations for the period 12UTC 9 May to 00UTC 12 May 1996. During this period a combined City College- Tribhuvan University team of researchers performed meteorological observations and measurements at the 3800m asl Hotel Everest View (HEV) and at the Italian weather research station Pyramid (Pyramid), 5050m asl, near Lobuche. Additional surface weather data was made available to us by the Italian Pyramid and by the Nepal Department of Hydrology and Meteorology which operates a weather station at Dingboche, 4350m asl.

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2. NUMERICAL SIMULATIONS

The 60 hours of ½ hourly simulations included two full diurnal cycles of valley winds. Using two-way, interactive, triple-nested interactive domains with 27, 9, and 3 km horizontal resolution, all default parameters, such as land use and topography, were left in tact. The results of the computer- smoothed topography, now deprived of its former highly complex nature, left in Domain 3 the N-S oriented Dudh Kosi-Tughla Khola-Imja Khola river system (Fig.1). This valley spans 60 km from south to north, 45 km from east to west at the north end (U-shaped) and 30 km from east to west at the south end (V-shaped). A 7000 + meters ridge surround the valley on all sides, except at its southern entrance and at its northwestern corner, where the elevation is 6000m. Elevation rise from south to north is 4400m; the valley side walls on the southwest and entire east section are extremely steep. The vegetation/land use assigned by the model along the N-S cross-section range from dry land and pastures at the southern end, to evergreen needle forests and mixed shrubs in the middle and grass plus barren, sparse vegetation up to 50km; the last 10km, 5400m and higher, consists entirely of snow and ice.

3. RESULTS

3.1 *Surface Winds on Cross-section AB*

First, a 60km south-to-north cross-section AB (Fig.1) along the model's valley axis from 3000 to 7000m indicated vigorous daytime valley flow at speeds of 10 to 15 m/sec from the south along the entire axis, up to just above 5000m, with duration several hours longer at the lower elevations. For locations below 4500m, the daytime layer of southerly flow reached a depth of close to 2000m at midday; this depth decreases at the higher elevations e.g. To 200m at 6000m asl. Nocturnal flows appeared to be affected by elevation. Below 4500m, wind speeds were 12 to 15 m/sec from the

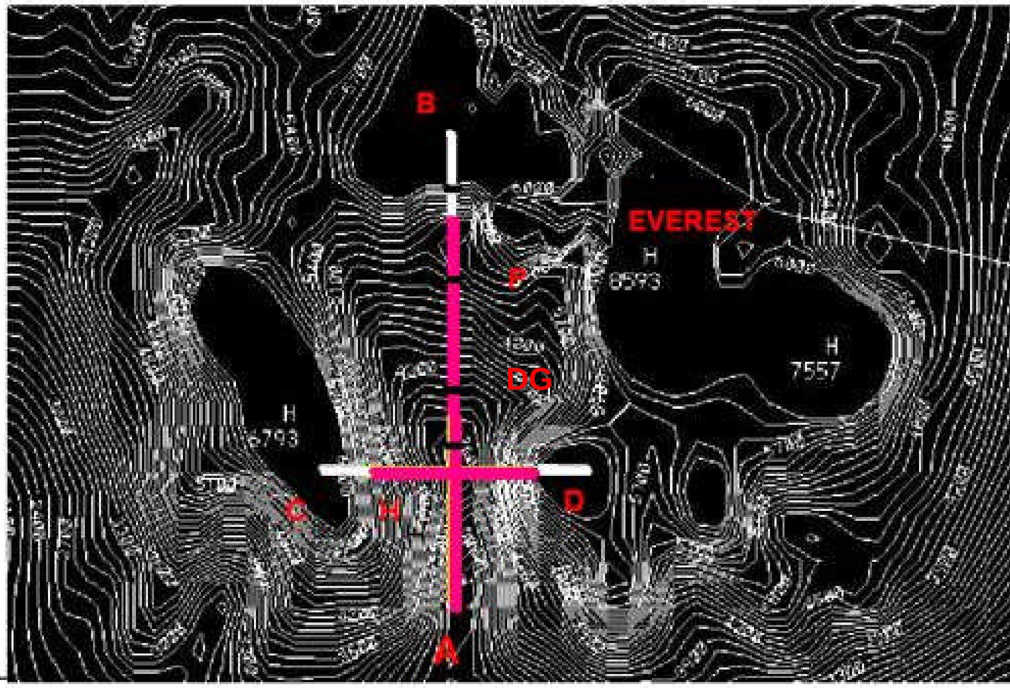

Figure 1. showing the topographical contours, 100m, of Domain 3 (resolution 3km) with X-sections AB and CD in red. White segments of the cross-sections denote snow and ice. Pink segments denote barren, sparse vegetation at the higher elevations and mixed shrubs and grass at the lower elevations. Black lines are at 3500, 4000, 5000 and 6000m respectively.

east and northeast, reaching a depth of 100m. The 5 to 7 m/sec, north and northwesterly winds at 5000m indicated reaction to and interaction with the upper air winds. The model also indicates the depth of these nighttime winds to be no more than 20 to 40m. On the 10km long, snow and ice covered section along the valley axis above 6000m, a 2 to 5 m/sec southerly daytime flow occurred for about 4 hours during the afternoons. Winds here were westerly at all other times at speeds of up to 20 m/sec. Duration of the transition from daytime to nighttime flows was 2 hours at 3500m, 2 to 6 hours at 4000m, 3 hours at 5000m and less than an hour at 6000m.

3.2 *MM5 and HEV Surface Winds*

In spite of the low, 3km resolution, the second set of analyses suggest remarkable agreement between our measured wind data and the simulated surface wind data. At the HEV, daytime wind speeds (Fig.3), 10 to 12 m/sec, and direction (Fig.2), from the south, were identical; wind speeds, 2 to 5 m/sec were similar. Directions during the evening transition were also somewhat similar, with the observed directions occasionally erratic and the model's consistently south and east. The duration of the transition period however, ~ 6 hours was identical. Nocturnal wind directions, northeast, south and west, were very similar as well. MM5, however, predicted nighttime wind speeds of up to 10 and 12 m/sec, identical to the day time speeds, but almost five times faster than the observed 3 m/sec. Our observed HEV wind data displayed a clear day/night wind speed asymmetry, but the MM5 predictions did not.

3.3 *MM5 and Dingboche Surface Winds*

The third set of analyses compared observed wind data from Dingboche, 4350m asl, with the MM5 predictions. Again, daytime wind speeds (Fig.5), 10 m/sec observed, 12 to 15 m/sec for the model and directions, southerly (Fig.4), were very similar. Dingboche observed data indicate an evening transition of ~ 2 hours at 2 to 6 m/sec; the model predicts a longer duration, ~ 4 hours at 2 to 10 m/sec. Nighttime wind directions from the north, northeast and east for both observed and MM5; observed nighttime wind speeds vary from 1 to 5 m/sec, confirming the day/night wind speed asymmetry. The model's predicted nocturnal wind speeds reach 12 m/sec, much like the model's daytime speeds.

3.4 *MM5 and Pyramid Wind, Temperature and Dewpoint Comparisons*

The final analyses compared the observed Pyramid, 5050m asl, wind, temperature and dewpoint data with MM5 predicted skewT profiles. Daytime wind directions from the southwest were almost identical (Fig.6), although wind speeds were markedly different, 1 to 5 m/sec for observed and 5 to 10 m/sec for the model (Fig.7). The MM5 evening transition showed signs of interference from westerly flows, beginning from 1600hrs at 5 to 10 m/sec and ending at 2300hrs when it settled into its nocturnal direction of 120 degrees, at the same speed. The observed winds began slowing down before 1500hrs and remained mostly calm, 0 to 1 m/sec, from a predominantly southwesterly direction from 2100 to 0800hrs the next day. Observed wind direction was consistently from the southwest, with occasional changes from the southeast and northwest. The observed day/night wind speed asymmetry occurred at Pyramid as well.

Temperature comparisons between the MM5 generated surface temperatures and those from the Pyramid did not fare so well. MM5 predicted surface temperatures were consistently 4C colder, did not exhibit the expected nighttime cooling and missed the typical, steep rise, ~ 8C of the observed surface temperature between 0700 and 0800hrs. Except for a 6 hour period during the day, the model consistently underestimated moisture at the surface. At 1830hrs when thunderstorms were occurring (Fig.8), and the observed dewpoints had increased to ~ 4C, the model's predicted dewpoints had decreased to -27C. During the night, MM5 underestimated surface moisture content by at least 10C.

5. CONCLUSIONS

These initial analyses suggest the following. The MM5 predictions indicate all the signs of the classic mountain-valley circulation. Very fast wind speeds result when surface friction is eliminated. The model's predictions of the shallow depths of the nighttime flows at 3500, 4000 and 5000m are noteworthy, because under complex terrain conditions, the speed of such a shallow layer will inevitably slow down. These shallow depths may be one of the reasons for the observed daytime/nighttime wind speed asymmetry. Also, a contributing factor could be that much of the surface above 4500m consists of rocky cliffs, rocks and boulders, which heat quickly during the day and retain their hear long after sunset (personal observation). The MM5 landuse categories do not include surfaces that are solid rock. Personal observations confirm the existence of the model's prediction of the exceptionally deep layer of daytime winds. Daytime and evening transition wind speed and directions at HEV and Dingboche plus nighttime wind directions were very similar, although the model predicts much faster nighttime wind speeds for both. MM5's predictions for surface wind speed, wind direction, temperature and dewpoints at Pyramid were less successful.

Severe thunderstorms occurred in the entire northeast and east areas of Nepal on May 10 and 11. The observed storms at HEV, Dingboche and Pyramid occurred between 1800 and 1930 hrs on those days. The model predicted thunderstorms for the east flank of the Everest massif between 1830 and 1930 on May 10 and only for the high mountain peaks surrounding the computer modified Dudh Kosi Valley between 1500 and 2200 hrs for May 11.These findings still indicate a potential that the MM5, perhaps with improved topography and land-use parameterizations, could become a useful tool for predicting severe pre-monsoon weather in the region of Mt. Everest.

6. ACKNOWLEDGEMENTS

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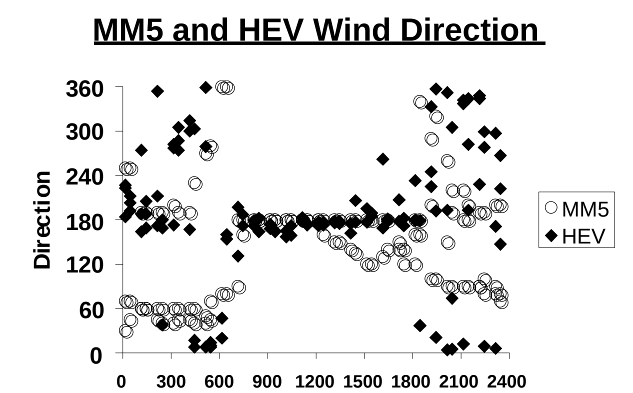

Figure 2. MM5 and HEV wind direction for the period1745NST 9 May to 0545NST 12 May 1996

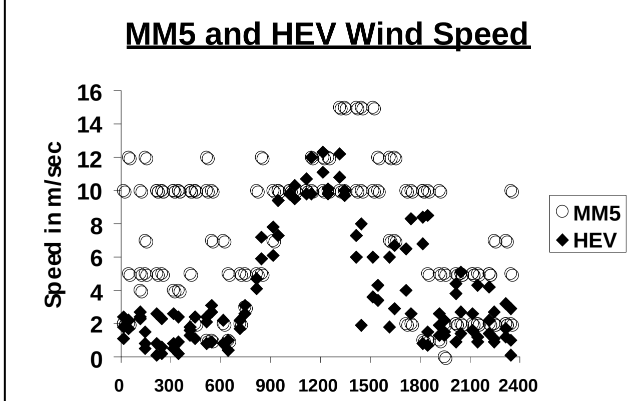

Figure 3. MM5 and HEV wind speed for the period 1745NST 9 May to 0545NST 12 May 1996

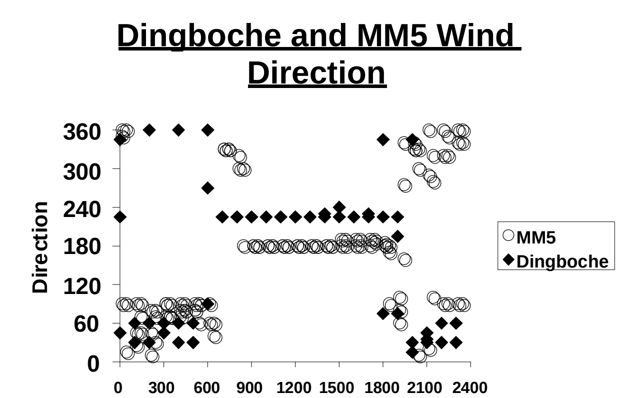

Figure 4. MM5 and Dingboche wind direction for the period1745NST 9 May to 0545NST 12 May 1996

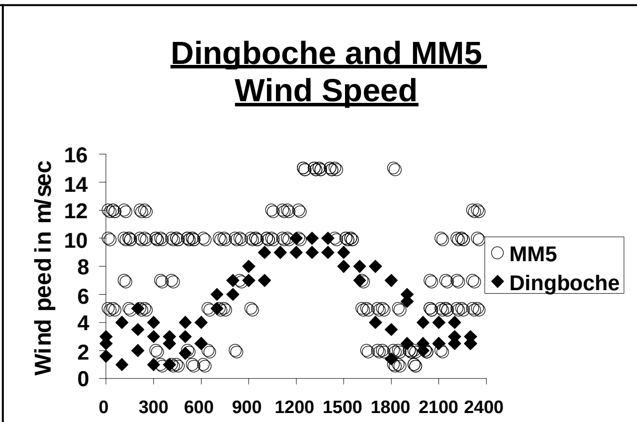

Figure 5. MM5 and Dingboche wind speed for the period 1745NST 9 May to 0545NST 12 May 1996

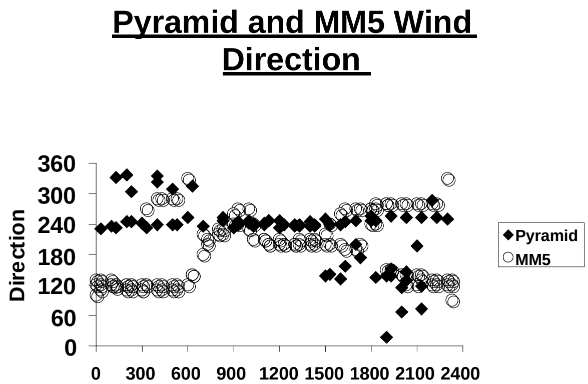

Figure 6. MM5 and Pyramid wind direction for the period 1745NST 9 May to 0545NST 12 May 1996

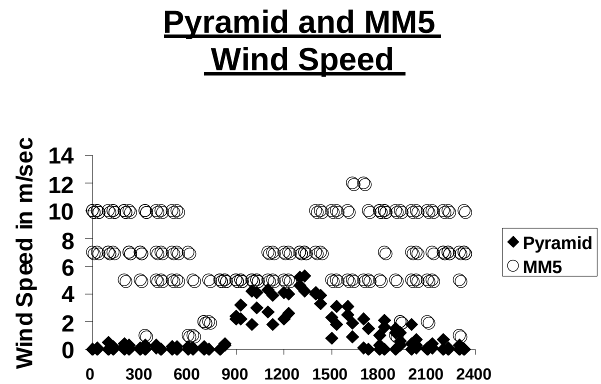

Figure 7. MM5 and Pyramid wind speed for the period 1745NST 9 May to 0545NST 12 May 1996

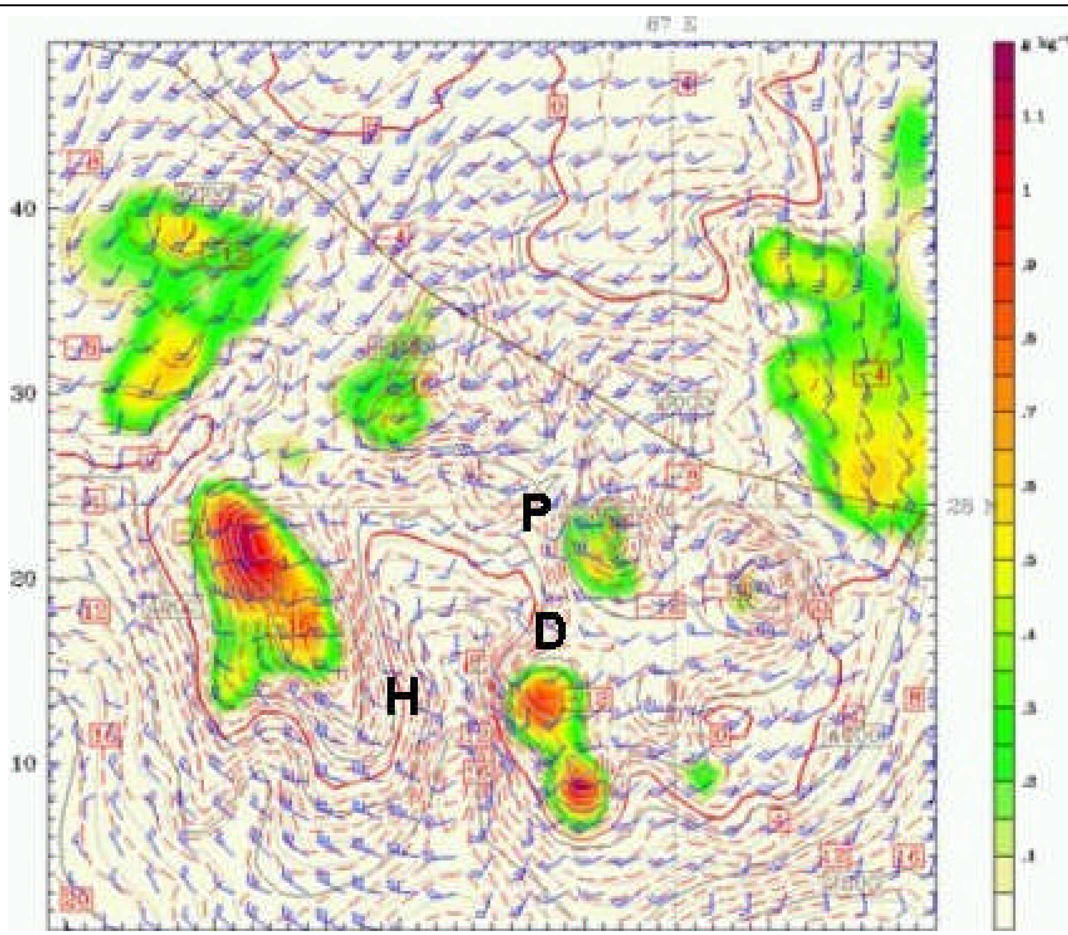

Figure 8. MM5 simulation of Domain 3, the Dudh Kosi Valley and Everest area, at 1600NST, May 11 1996. The model predicts thunderstorms only on mountain peaks to the east and west of the valley between 1500 and 2200NST on May 11.