A Comparison of the New OSU LSM and 5-Layer Soil Models Using a Dugway Proving Ground Salt Breeze Simulation

Daran L. Rife[1], Thomas T. Warner[1], Fei Chen[1], and Elford Astling[2]

1. National Center for Atmospheric Research, Boulder, Colorado
2. U.S. Army West Desert Test Center, Dugway, Utah

1. Introduction

Arid and semi-arid climates (deserts) comprise approximately 40 percent of the Earth's land area. By comparison, only 10 percent of the land surface is cultivated. In recent years population growth in arid areas has often surpassed that in more temperate zones. Thus, desert climate is having a direct impact on a growing fraction of the world population.

A land feature unique to desert environments is known as playa. Playas are bare-soil depressions or flat basin floors. Most of the larger playas were lakes during previous pluvial periods, and the smaller ones originated as a result of regional erosion patterns. There are over 50,000 playas on Earth (Rosen 1994), and in North America there are approximately 300 playas with areas more than 5 km^2.

Playa soils have physical properties that exert strong controls on the surface heat and water budgets. These properties include high albedo, high thermal conductivity, and large heat capacity. The soil moisture content can also be large if the water table is high, or from recent precipitation.

The physical properties of playa soils strongly contrast with those of the surrounding desert. This often forces local and regional scale circulations. One such circulation is known as the salt breeze, first identified by Tapper (1988). The salt breeze is a thermally direct circulation analogous to the well-known sea breeze, but results mainly from differences in albedo and thermal conductivity between the playa and the surrounding desert soils. However, the moisture content of the playa soil can also play an important role.

During the daytime the high albedo and high thermal conductivity of playa soils keep surface heating low compared to the surrounding desert. Thus, the lower playa temperatures induce a local surface high pressure. In this situation, air diverges and flows down gradient and off the playa (see Fig. 1).

The high specific heat of the playa soil allows ample energy to be stored during the day. This stored energy warms the lower atmosphere through the night, keeping temperatures higher over the playa and inducing a local surface low pressure. A convergent area then develops

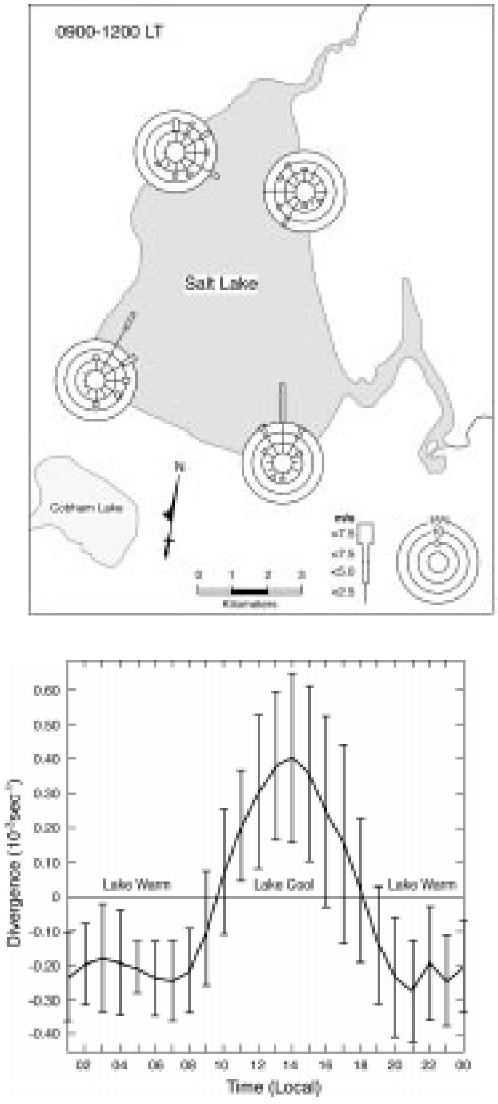

Fig. 1. (a) Wind rose statistics from a dry salt lake (playa) in Australia showing airflow off the lake (cool playa) during daytime. **(b)** Divergence calculated from wind statistics shown in **(a)**. [After Tapper, 1988].

with air flowing onto the playa. These circulations are an important contribution to the local climate of many deserts worldwide, and occur at the Dugway Proving Ground, in Utah (hereafter, referred to as DPG).

2. Experiment Design

Regional climate modeling essentially reduces to simulating fine-scale interactions between the Earth's surface and the atmosphere. A new physics package was recently implemented in the PSU/NCAR MM5, which has been advertised as being capable of accounting for these fine scale interactions. This package is referred to as the LSM (an adapted version of the Oregon State University Land Surface Model; see Chen and Dudhia, 1999).

It is reasonable to ask whether the LSM (a new and sophisticated package) can produce better simulations of playa breezes than the widely used (and tested) 5-layer soil model (Dudhia, 1996). Therefore, two experiments have been performed in a case study setting. One simulation employs the 5-layer soil physics option and the other utilizes the LSM physics package.

Four nested computational domains were employed in the case study simulations (see Fig. 2); the outer domain features a 30 km grid spacing, and the finest-scale domain has a grid spacing of 1.1 km. All domains use 31 vertical levels, with a model top of 50 mb. The non-soil physics options used include; 1) the Grell cumulus parameterization scheme (Grell, 1993) on the 30 and 10 km domains; 2) the MRF PBL scheme (Hong and Pan, 1996); 3) the Dudhia radiation scheme (Dudhia, 1989); and 4) the simple ice microphysics scheme (Dudhia, 1989).

3. Overview of the Case Study Period

Salt breeze circulations are generally only distinguishable from larger scale circulations when weak synoptic and clear sky conditions exist. The present case study was conducted for 14 July 1998, a day typified by weak synoptic flow and clear skies. Surface observations at DPG indicated the development of a salt breeze circulation in the afternoon hours.

This date also coincides with a field campaign at DPG, during which fairly high spatial and high temporal surface and radiosonde observations were collected. The surface observation dataset included measurements of soil moisture, water table depths, surface solar radiation, and surface sensible and latent heat fluxes.

4. Results

Figure 3 shows the fine scale (1.1 km) domain results valid at 2200 UTC (1500 LT) 14 July 1998 from the simulation employing the LSM, and the corresponding surface observations.

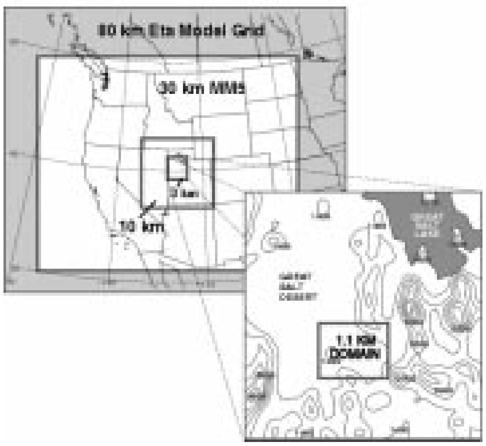

Fig. 2. MM5 configuration for the case study simulations. Domain 3 (3.3 km resolution) is expanded and terrain is contoured with an interval of 200 m. [From Davis, et al., 1999].

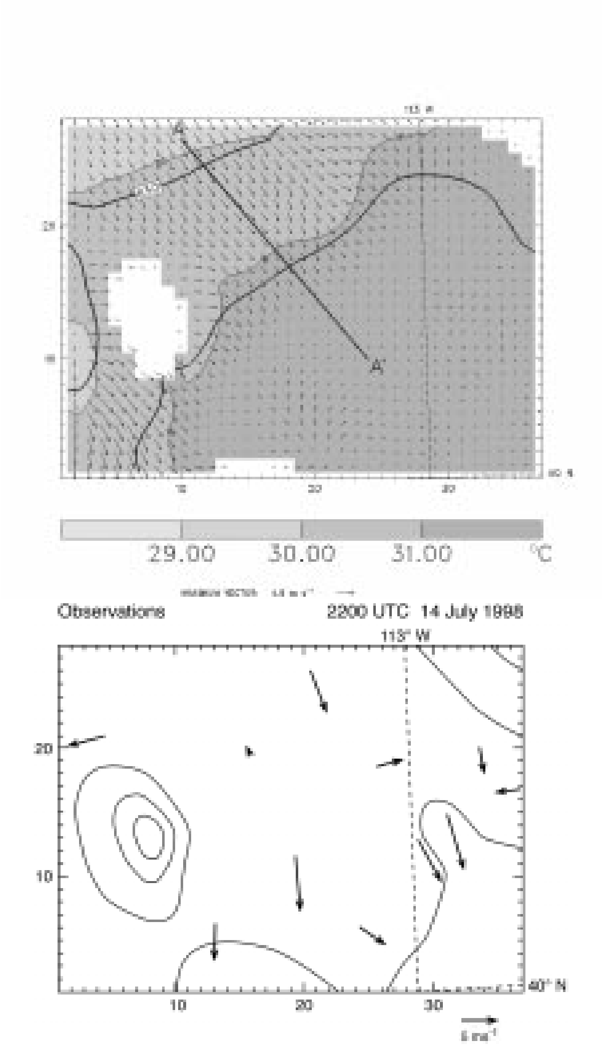

Fig. 3. Fine scale domain (1.1 km) results from the simulation employing the LSM. **(a)** Temperature (C), winds (ms^{-1}), and pressure (mb) are shown at Z=1.5 km. **(b)** Corresponding plot of surface observations.

The figure clearly shows a small scale fontal and circulation structure. Figure 4 shows a vertical cross section along *AA'* in Fig. 3. A thermally direct circulation is evident with lower temperatures over the playa (left-hand side of the figure) and higher temperatures over the surrounding desert (right-hand side of the figure). The surface temperature distribution is Fig. 3 is reasonably consistent with observations.

The simulation using the 5-layer soil model also develops this circulation, but incorrectly depicts an excessively strong surface temperature contrast (roughly 5 C) between the playa and the surrounding desert (not shown). Therefore, these preliminary results indicate that the LSM solution is somewhat superior to the 5-layer soil model solution.

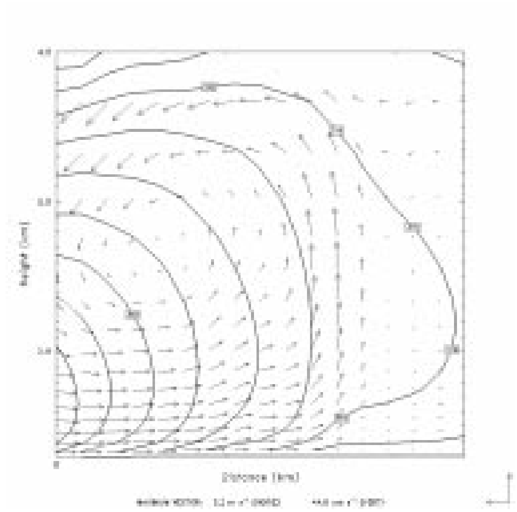

Fig. 4. Vertical cross section (along *AA'* in Fig. 3) showing predicted potential temperature (K) and wind parallel to the cross section (ms^{-1} horizontal; cms^{-1} vertical). Potential temperature is contoured every 0.25 K.

5. Summary and Future Work

These early results indicate that the LSM is capable of simulating fine scale interactions between the Earth's surface and the atmosphere; in this case the DPG salt breeze circulation. It also appears that the LSM produces slightly superior results than the 5-layer soil model.

Future work will include a full suite of salt breeze sensitivity tests using the LSM. The intent is to ensure that we fully understand the physical mechanisms involved in developing the salt breeze circulation at DPG, and the sensitivity of the LSM scheme itself to various surface parameters.

6. References

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