Estimation of precipitation climatographies using atmospheric models

Scott Swerdlin and Thomas Warner

Introduction

High horizontal-resolution estimates of precipitation characteristics in data-sparse regions are necessary for understanding the details of the hydrologic cycle and for formulating water-resources-management policy. Even though satellite data are sometimes available for providing information, model-based estimates are complementary and sometimes better. This paper describes a method for dynamically downscaling with atmospheric models to provide fine-scale, gridded estimates of precipitation for areas with poor conventional data coverage.

The Penn State/National Center for Atmospheric Research community mesoscale model, MM5, has been adapted so that it can provide high-resolution depictions of the regional precipitation climate, as well as soil moisture and evaporation rate. The geographic focus area of the case to be reported on here is the eastern Mediterranean and the adjacent countries of the Middle East, where the Mediterranean Sea and some areas of the Middle East represent large voids in terms of conventional data. Even though satellite estimates of rainfall are themselves imperfect, they are used to infer that the model is reasonably replicating the small-scale aspects of the precipitation climate.
In summary, this modeling system enables the generation of high-resolution, 4-dimensional gridded analyses of the atmospheric and surface hydrologic cycle for use in water-resource analyses, flood potential, and physical-process studies. The study described here demonstrates the success of the modeling system, which can be re-applied for any area of the world. Preliminary results from this study can be found in Hahmann (2007). Further results are presented here.

An example of the downscaling

For this test, the model has been run for eight Januaries (2000-2007) and eight Julys (1999-2006) using NCAR-NCEP Reanalysis Project archived global analyses for lateral-boundary conditions. Surface and upper-air observations are assimilated on the model grids to provide the best possible model climatography of the region. Figure 1 (lower right) shows the average January precipitation based on MM5 simulations, for the inner computational domain (15 km horizontal grid spacing). Significant precipitation maxima over land are along the coastlines of the Levant, Turkey, and Greece. There is also significant precipitation over the Mediterranean to the south of Greece. The precipitation gradient is very large along the North African coastline. The gradient is somewhat less along the Levant and Turkey coasts, but it is still large. The coastal amounts from the TRMM satellite/gauge merged data show a similar pattern (upper right), but there is less precipitation estimated over the central and southern Mediterranean. An analogous comparison for July is shown in Fig. 2. The inter-annual variation in monthly precipitation averaged over a land area in southwest Turkey is shown in Fig. 3a. This area was selected somewhat arbitrarily near a maximum in MM5-

simulated precipitation to illustrate a typical regional year-to-year variability. The MM5 simulation consistently underestimates the land precipitation amounts as compared to the gauge-, GPCC-, and merged TRMM-derived area averages. However, this underestimation might simply be an artifact of the selected averaging region; in areas of large rainfall gradients, such as the one chosen, small horizontal shifts might cause large differences in the area-averaged precipitation. Nevertheless, the percent variation from one year to the next is well represented in the MM5-simulated rainfall. Figure 3b compares the area-averaged MM5 and NNRP cyclone-center counts for an area that roughly corresponds to that used in the precipitation averages. This area is one of the regions where cyclones occur most often, based on the 18-year climatology of Trigo et al. (1999). There is agreement between MM5 and NNRP in the year with the most cyclones (2004) and in the year with the fewest (2002), but there are otherwise significant differences. However, the year-to-year variation in NNRP and MM5 cyclone frequencies show a similar behavior to that of the observed inter-annual variations in rainfall for both the model and the observations.

Figure 4 shows a comparison between radar-based and model estimates of precipitation for two Januaries. Clearly the model captures the annual variability on this meso-gamma scale.

Summary

The results described here illustrate a preliminary assessment of the ability of the MM5 model, using continuous assimilation of observations, to downscale precipitation for the eastern Mediterranean and surrounding land areas. This work is the initial phase of a larger project that is aimed at building a system that is able to downscale changes in the water cycle that result from the climate change predicted by a low-resolution atmospheric general circulation model. Results from the system will be especially relevant for other water-limited regions of the world.

References

Hahmann, A. N., D. Rostkier-Edelstein, **T. T. Warner**, Y. Liu, F. Vandenberghe, S. P. Swerdlin, 2007: Climate downscaling for the eastern Mediterranean. *Advances in Geosciences* (EGU), **12**, 159-164.

Trigo, I. F, T. D. Davies, and G. R. Bigg: Objective climatology of cyclones in the Mediterranean region, J. Climate, 12, 1685–1696, 1999.

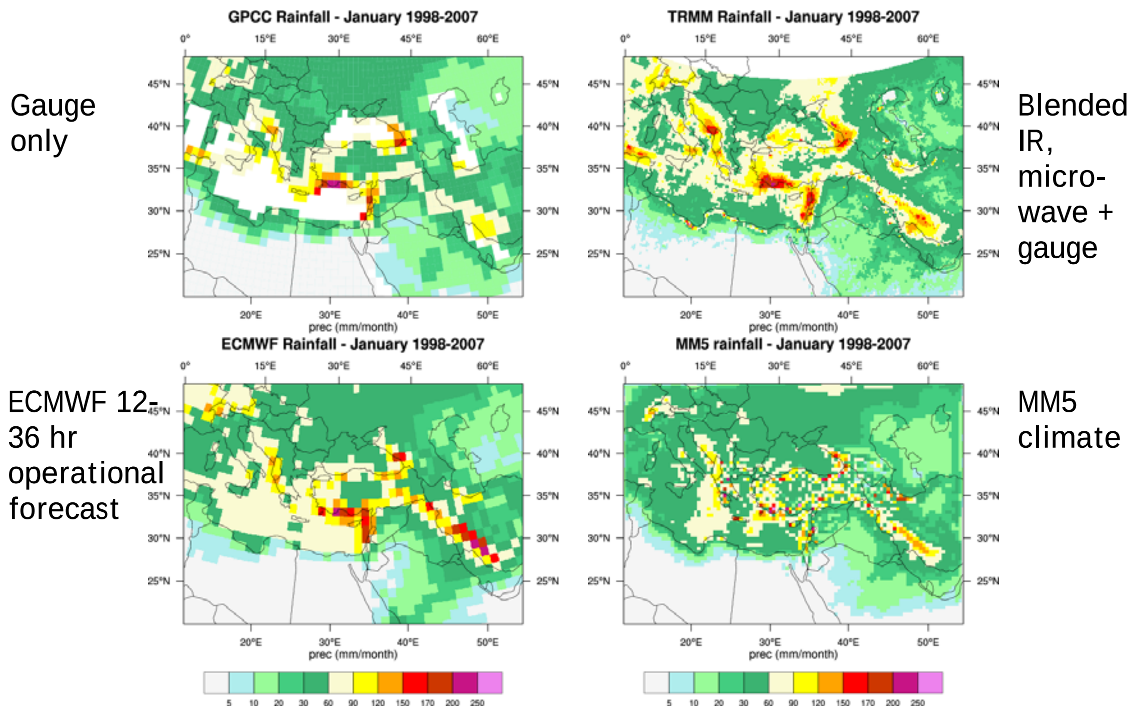

Figure 1. January precipitation average (8 years) based on gauge data (upper left), TRMM merged satellite and gauge data (upper right), ECMWF forecasts (lower left), and the MM5 downscaling (lower right).

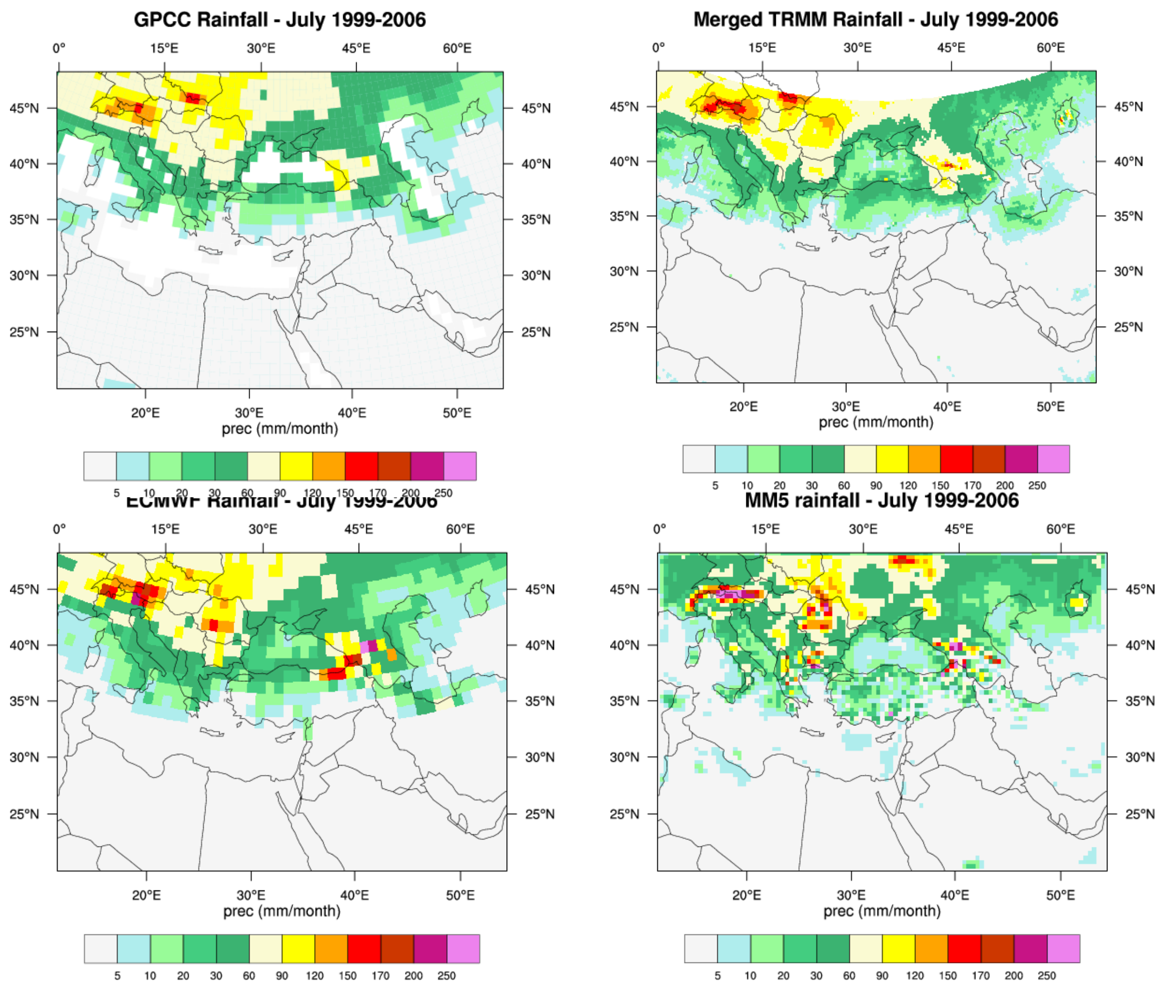

Figure 2. Same as Fig. 1, except for July.

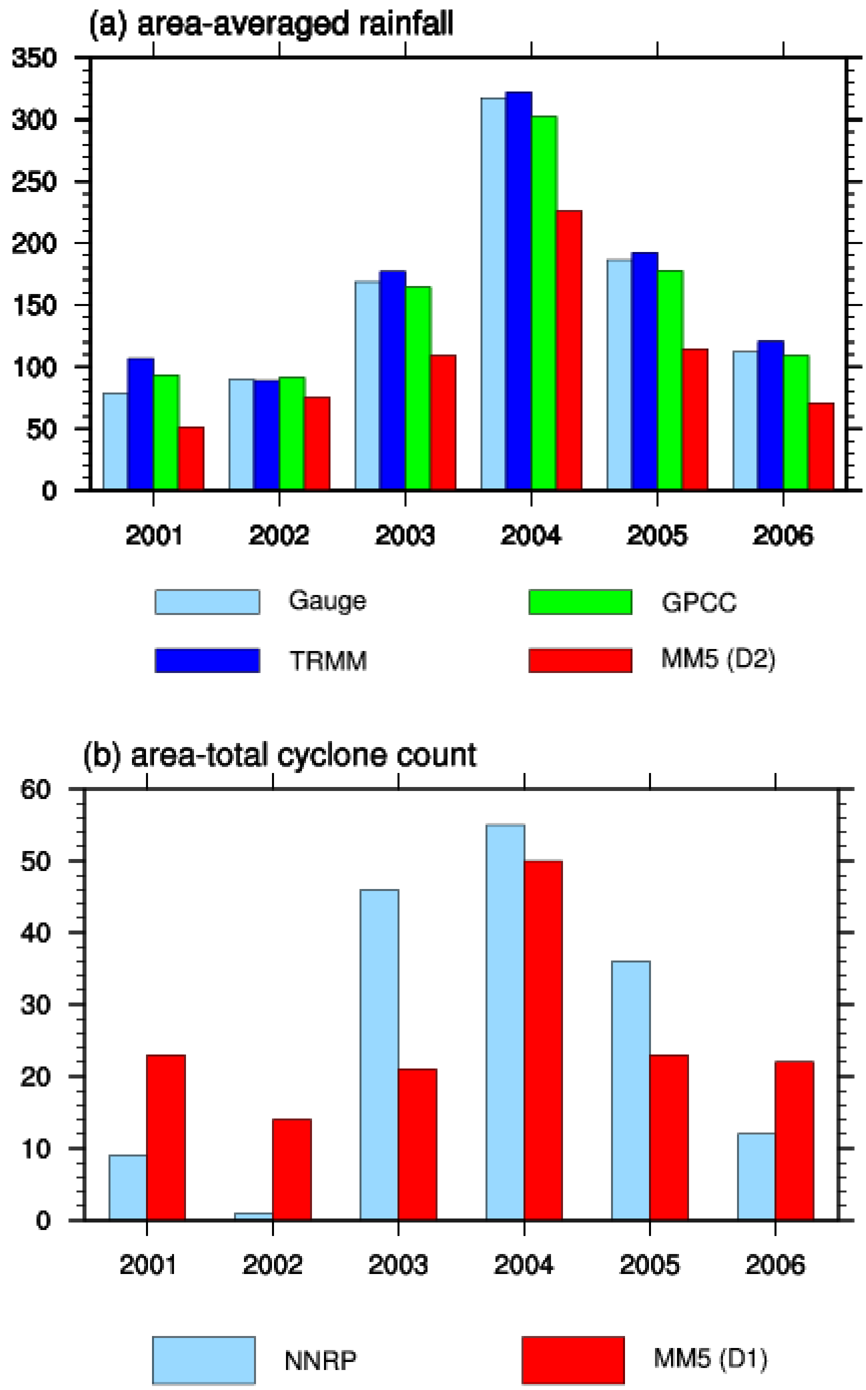

Figure 3. For the land area within the box to the southwest of Turkey in Fig 2a, the annual variation in the January-average precipitation based on data from various sources (a) and the number of cyclones whose centers passed through this area (b). These cyclone-count data are based on the 6-hourly sea-level pressure fields described in the text. The precipitation values consider only the land-area, so that gauge data could be included. Information about precipitation data from the Global Precipitation Climatology Centre (CPCC) can be found at http://www.dwd.de/en/FundE/Klima/KLIS/int/GPCC/.

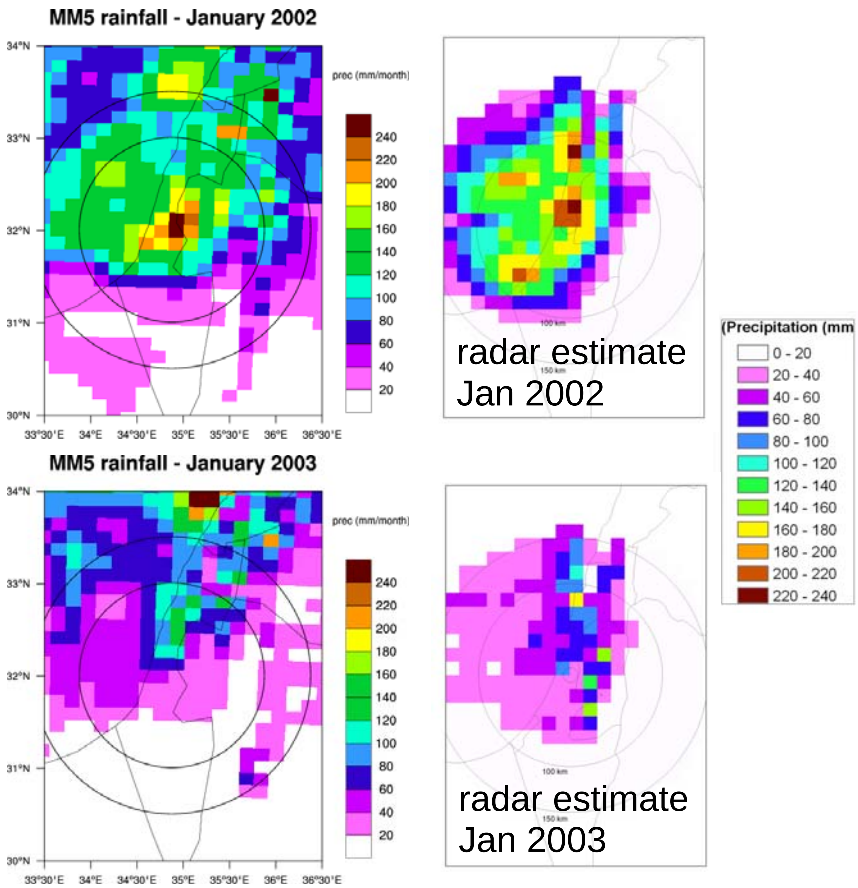

Figure 4. Comparison of model-simulated (left) and radar (right) estimates of precipitation for two Januaries. Dr. Efrat Morin, Hebrew University of Jerusalem, provided the radar estimates.