Simulation of the Low-Level Jet by General Circulation Models

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To what degree is the low-level jet (LLJ) climatology and its impact on clouds and precipitation being captured by current general circulation models (GCMs)? My hypothesis is that current GCMs do not simulate the relationship between clouds and the LLJ, so that a parameterization will be required. Here I evaluate the need for a parameterization.

To assess the simulation of the LLJ, I use the LLJ criteria of Bonner (1968). I applied Bonner's criteria to the winds simulated by two GCMs, namely the European Center for Medium-Range Weather Forecasts (ECMWF) model and the National Center for Atmospheric Research Community Climate Model (CCM2). Both models were run at T42 resolution, with the ECMWF model driven by sea surface temperatures observed during the Atmospheric Model Intercomparison Project period 1980-1989 and the CCM2 driven by climatological mean sea surface temperatures. The ECWMF simulation was performed by the Program for Climate Model Diagnoses and Intercomparison (PCMDI) at Lawrence Livermore National Laboratory. My analysis focuses on the ECMWF simulation for 1980-1982 and the CCM2 simulation for 3 years. Figure 1 shows the spatial distribution of simulated LLJ frequency for Bonner criterion 1, using 6-hour samples. The LLJ frequency distribution simulated by the ECMWF model is remarkably similar to that estimated from observations (Bonner 1968), with the maximum frequency of about 30% occurring over Oklahoma, and frequencies of less than 5% over most of the eastern and western United States. The LLJ frequency distribution simulated by the CCM2 also exhibits a (somewhat weaker) maxima over Oklahoma, with a minima on the Gulf coast as observed (Bonner 1968). Helfand and Schubert (1994) found a very similar distribution of the LLJ frequency simulated by the Geostationary Operational Environmental Satellite-1 model. The nocturnal maximum of the LLJ frequency and intensity is also simulated quite well by all three GCMs. Interestingly, all three GCMs also simulate a frequent LLJ off the coast of California.

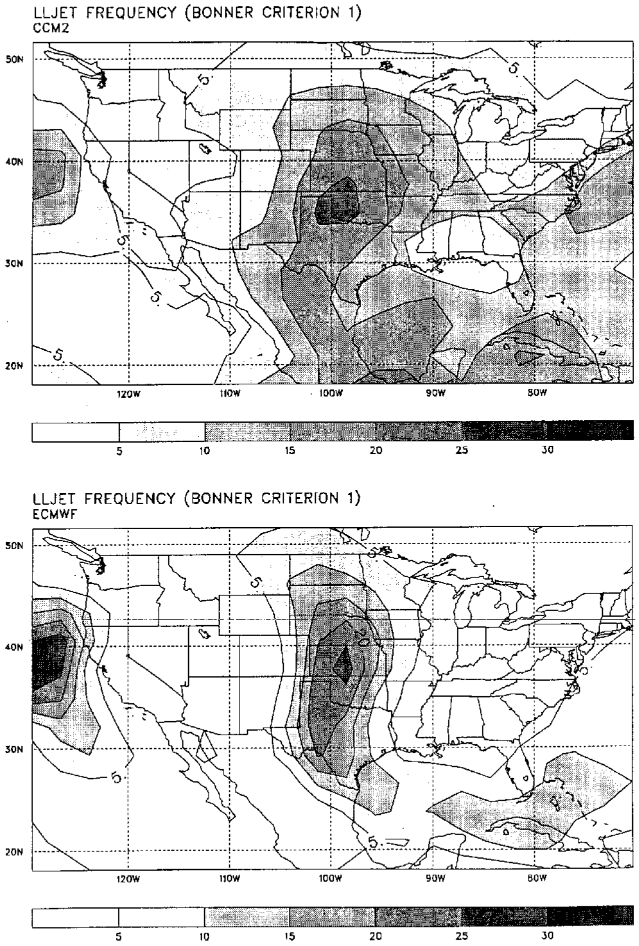

Figure 1. Frequency of LLJ (Bonner criterion 1) simulated by CCM2 (above) and ECMWF (below) models for a period of three years.

It appears that at least some GCMs can simulate the LLJ, so the LLJ itself need not be parameterized. However, the influence of the LLJ on clouds and precipitation may still need to be parameterized. To evaluate the need for parameterizing this influence, I have examined the diurnal cycle of the convective precipitation rate simulated by the ECMWF and CCM models. Convective precipitation is strongly related to the occurrence of thunderstorms (Slingo 1987). Hering and Borden (1962) and Pitchford and London (1962) have shown that associated with the LLJ is a nocturnal maximum in convective activity over the central United States (Wallace 1975). Thus, one means of evaluating the simulation of the influence of the LLJ on clouds and precipitation is to examine the diurnal cycle of the simulated convective precipitation, shown in Figure 2 for the ECMWF model and for CCM2. Neither GCM simulates a significant nocturnal maximum in convective precipitation in the central United States. Thus, it appears that the influence of the LLJ on convective clouds and precipitation will have to be parameterized.

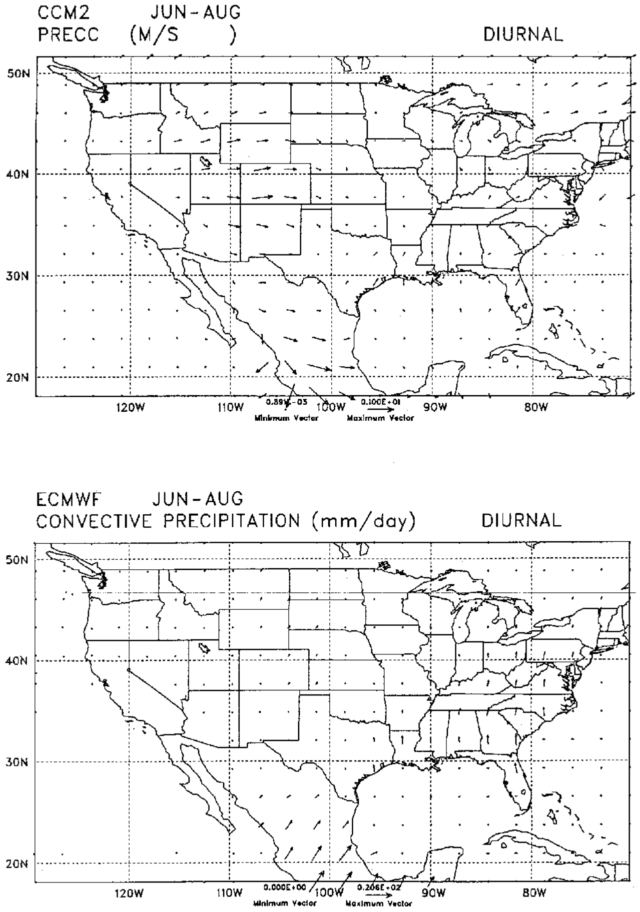

Figure 2. Amplitude and phase of diurnal cycle of convective precipitation simulated by CCM2 (above) and ECMWF (below) models for three years of June-July-August. Phase is local midnight for vectors pointing southward, 6 a.m. for vectors pointing westward, etc.

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