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Factor Separation Analysis of the Diurnal Temperature Range Using the WRF Single Column Model

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The decreasing trend in diurnal temperature range (DTR), primarily owing to an asymmetric increase in minimum and maximum temperatures, is one of the clearest signals found in 20th century climate data. Climate models have been unsuccessful in simulating this effect fully, making it increasingly important to understand the reasons for this change. A factor separation analysis of the DTR was conducted, using the WRF Single Column Model, for summer and winter in a number of locations around Israel. Atmospheric moisture (water vapour, clouds and all hydrometeors), geostrophic winds (representing different air masses) and a doubling of GHGs were studied, by running the model with each factor switched on and off in turn. Using the factor separation method, the pure contribution of each factor as well as the contribution of their mutual interactions on the DTR was thereby determined. Israel presents an interesting area for this study given it lies on a sea-desert border with complex topography, leading to a large variation in climate over small distances. For the days investigated the DTR was found to range from 14.6 to 22.3K and 5.6 to 16.2K for summer and winter, respectively.

Atmospheric moisture was found to clearly be the dominant factor for both seasons, reducing the DTR primarily due to increased minimum temperatures. A substantial difference was found between the seasons, with values reaching -11.0K in summer, while in winter they did not exceed -7.4K. The pure contribution of doubled GHGs was also a reduction in DTR, again through increased minimum temperatures. This effect was much smaller than that of moisture and did not exceed -0.5K, similar to moisture the effect was found to be larger in summer. The synergy of GHGs and moisture increased the DTR for all days, with the exception of a few days in winter. This contribution is opposite in direction to the pure effect of each factor, the two compete for the IR absorption of the same wavelengths, the resulting absorption is therefore not equal to the sum of each alone. The magnitude of this effect was found to be only slightly smaller than the pure effect of doubling GHGs.

For both seasons the contributions which include geostrophic wind vary between increasing and decreasing the DTR. Its pure effect varies from -4.4 to 3.0K with some days showing no effect at all. The contribution which results from its interaction with moisture is also substantial, varying from -3.1 to 2.2K. Unlike the other two factors these contributions were larger in winter, thought to result from the larger inter-daily variation in synoptic conditions observed compared to summer. These result in geostrophic winds bringing a greater variation in moisture, storms and fronts and leads to the larger contributions to the DTR observed. This has little effect on the GHGs, indeed the geostrophic wind and GHG synergy is consequently small, and comparable for both seasons.