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DEVELOPMENT OF A CATCHMENT-BASED HYDROMETEOROLOGICAL FORCING DATA SET FOR LAND SURFACE MODELING APPPLICATIONS

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1. INTRODUCTION

The Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) phase II has demonstrated that runoff and evapotranspiration are not well represented in many land surface modeling schemes (Lohmann *et al.* 1998). It was suggested by Koster and Milly (1997) that this was a result of incompatibility between runoff and evaporation formulations. Koster *et al.* (2000) have addressed this problem through development of a catchment-based Land Surface Model (LSM). This model is unique in that partitioning of the land surface is by hydrologic watershed rather than the standard atmospheric gird. Moreover, topographic control is used as a means for partitioning water and energy computations, based on the framework proposed by Famiglietti and Wood (1994).

Uncoupled runs of the LSM require off-line atmospheric forcing data to undertake model simulations. Presently, many modelers use the forcing data set provided by the first International Satellite Land Surface Climatology Project (Sellers *et al.* 1995). This initiative spans the years 1987-1988, a time frame too short for the purposes of seasonal-to-interannual prediction. To meet these objectives, a long term (15 year) catchment-based, bias-reduced hydrometeorological forcing dataset has been developed for the following variables: two meter temperature and dew point, ten meter mean wind speed, convective and total precipitation, long and short wave downward radiation, and surface pressure.

Currently, the only sources of complete/consistent data available at the temporal and spatial resolutions required by LSMs are in the form of re-analysis products. The problem associated with re-analysis products is that they are biased by the underlying GCM used to make the forecast. Therefore an important contribution of this dataset is the reduction of bias for each of the forcing fields by adjustment of the re-analysis fields to match monthly mean observations. The steps taken to reduce bias in the temperature, dew point temperature, short and long wave radiation, precipitation and surface pressure forcing fields are presented.

2. METHODS

The data used in the development of a catchment-based hydrometeorological forcing data set is the European Centre for Medium-Range Weather Forecasts (ECMWF) re-analysis, having a grid resolution of approximately 1.125 degrees and temporal resolution of 6 hours. Since the data set was to be catchment-based, for direct application to the catchment-based LSM of Koster *et al.* (2000), both re-analysis and observation data sets were interpolated into the approximately 0.5 degree catchment space. In this way, keeping the number of interpolations to a minimum minimized interpolation error. Moreover, re-analysis and observation data sets were on different grids. Delineation of the catchment boundaries is after Verdin and Verdin (1999). Discussion below will focus on bias reduction in the catchment space forcing fields.

2.1 Corrections for Temperature and Dew Point

The ECMWF re-analysis two-meter air temperature data was provided at the geopotential rather than at the land surface. Thus, to enable comparison between the re-analysis and observation data sets, both data sets were corrected to air temperature at sea level by means of the environmental lapse rate before interpolating into catchment space. The observation data were corrected to sea level using a digital elevation model (DEM) constructed from GTOPO30 (Gesch *et al*., 1999). The observation data used in the bias correction of air temperature was the result of merging the global air temperature observations compiled by New *et al.* (2000) and a newly extended version of Legates and Willmott (1990).

Once both observation and re-analysis data were corrected to sea level and interpolated into catchment space, the re-analysis data could be bias-corrected. For each month, the re-analysis monthly average temperature was compared to observations and the difference between observations and re-analysis used to perform a difference-based correction to the re-analysis. The final step involved raising the bias-corrected temperature back to the mean catchment elevation as determined from GTOPO30.

At the global to continental scales no observation datasets were found for relative humidity or dew point. Therefore, corrections to dew point temperatures were calculated from the bias in air temperature and elevation corrected dew point temperature and relative humidity calculated from the re-analysis.

2.2 Corrections for Downward Short and Longwave Radiation

Shortwave downward radiation was corrected in a similar manner to the methodology used by ISLSCP Initiative I:

$$S = \frac{S(S)}{AVG\left[\frac{S(N)}{1-A}\right]} * \frac{S(N)}{1-A}, \quad (1)$$

where S is the bias corrected surface shortwave downward radiation (6 hourly), S(S) is observed monthly surface shortwave downward radiation from the Langley Shortwave and Longwave surface radiation budget dataset, S(N) is the average surface net radiation (6-hourly) from the ECMWF re-analysis, A is observed albedo also from the Langley Shortwave and Longwave surface radiation budget dataset, and AVG represents a monthly average.

Bias correction to longwave surface radiation was also calculated in a similar manner to the methodology used by ISLSCP:

$$L = \frac{L(L)}{AVG[L(N)]} * L(N) + 0.996\,[b] * \left[T(S(t)) + \frac{T(S(t-1))}{2} \right]^4 , \quad (2)$$

where L is the bias corrected surface longwave downward radiation, L(L) is observed monthly surface longwave net radiation from the Langley Shortwave and Longwave surface radiation budget dataset, L(N) is the average surface net longwave radiation (6-hourly) from the ECMWF re-analysis, b is the Stefan-Boltzman constant, and T(S(t)) is surface temperature from the ECMWF re-analysis at time t.

The surface radiation budget observations are only available for the period 1983-1995. Corrections for time periods not covered by observations are based on regression equations between monthly observations and the ECMWF re-analysis. The regression equations are calculated for each catchment, but only applied where an adequate regression relationship could be determined, as evaluated by the root mean square error. In catchments where an adequate regression relationship could not be determined, the raw ECMWF radiation estimate was applied.

2.3 Corrections for Precipitation

Precipitation fields in the ECMWF re-analysis were corrected by a composite of three observation datasets; the Climate Research Unit half degree monthly time series (New *et al.* 2000), the Center for Climatic Research (University of Delaware) half degree global land surface precipitation and the one degree Global Precipitation Climatology Project (Huffman *et al.* 1997) data set. The mean of the three observation datasets was established and the composite interpolated to catchment space. Differences with re-analysis precipitation were recorded and a ratio-based correction applied.

Over several catchments, no precipitation was recorded in the re-analysis, thus, making a ratio-based correction impossible. To correct precipitation over these catchments, a logistic regression was performed using the ECMWF parameters; precipitable water content, relative humidity and cloud cover. The result of the equation is a coefficient representing the probability of precipitation for the six hour time period. Precipitation was then applied over the catchment for the time period with the highest probability at a rate equivalent to the monthly median amount of 6-hourly precipitation multiplied by probability coefficient. This process was repeated for the time step with the next highest probability until the monthly shortfall of precipitation over the catchment in question was overcome.

3. SUMMARY

Steps taken to reduce bias in the ECMWF re-analysis dataset in catchment space are presented. The resulting dataset provides long-term, consistent forcing fields for use in catchment-based simulations.

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