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A GLOBAL, 50-YEAR DATASET OF SURFACE ENERGY AND WATER FLUXES AND STATES

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1. INTRODUCTION

Off-line computer simulations of continental- and global-scale water balances are valuable for studying climate variability/change and the hydrological implications thereof. A global, multi-decade, daily, 2.0°, terrestrial meteorological forcing dataset is used to drive model simulations of the global water and energy balance. These simulations provide a long-term, globally consistent and validated set of land surface water and energy fluxes and states at a high temporal and spatial resolution. This dataset will facilitate the study of seasonal and inter-annual variability studies to an extent not possible with currently available datasets. It will also be suitable for evaluating the ability of coupled models and other land surface prediction schemes to reproduce observed variability of surface fluxes and state variables in space, and temporally for time scales up to decadal.

2. VIC MODEL

The land surface hydrology model used in this study is the Variable Infiltration Capacity (VIC) model, which has been applied to such large continental scale river basins such as the Columbia (Nijssen et al., 1997), the Arkansas-Red (Abdulla et al., 1996), and the Upper Mississippi (Cherkauer and Lettenmaier, 1999), among other rivers. The model has also been applied globally for a fifteen year period by Nijssen et al. (2001a). A detailed description of the model can be found in Liang et al. (1994, 1996 and 1998).

The VIC model simulates both the surface energy and water balances, typically at grid resolutions ranging from a fraction of a degree to several degrees latitude by longitude. Some of the distinguishing characteristics of the model are the representation of subgrid variability in soil moisture, land cover and topography and the representation of drainage from the lowest soil moisture zone as a non-linear recession. The model can be operated in two modes: (1) an energy balance mode, where all the water and energy fluxes near the land surface are calculated, and the surface energy budget is closed by iterating over an effective surface temperature; and (2) a water balance mode, where only the surface water balance fluxes are calculated and the effective surface temperature is assumed equal to the air temperature.

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3. INPUT DATA AND MODEL IMPLEMENTATION

3.1 Meteorological Forcings

The meteorological forcing dataset is constructed from a combination of existing global datasets. Precipitation is derived from the Climatic Research Unit (CRU) monthly precipitation product and is downscaled to a daily time step using the following two products: (1) the 15-year gauge-based dataset developed by the surface water modeling group at the University of Washington (UW), and (2) the NCEP/NCAR Reanalysis product. Use of the NCEP/NCAR product for downscaling is advantageous because other forcing variables (e.g., temperature, wind speed) can also be derived from the reanalysis. Comparison of the above two datasets indicated a spurious wave-like pattern in the NCEP/NCAR monthly wet day frequency and precipitation totals in the winter of the Northern Hemisphere high-latitudes. This is corrected using inter-monthly statistics from the UW dataset and monthly wet day frequencies from the CRU dataset. Temperature and wind velocity are derived from the NCEP/NCAR Reanalysis product. The other meteorological forcings, such as vapor pressure and radiation are estimated indirectly. Vapor pressure is calculated from dew point temperature, which is derived using the method of Kimball et al. (1997). Downward shortwave radiation is calculated based on daily minimum temperature and dew point temperature, following Thornton and Running (1999). Net longwave radiation is calculated based on the method of Bras (1990).

3.2. Topography, Soils and Vegetation

The topography, soils and vegetation data is obtained from the dataset of Nijssen et al. (2001a). Elevation data of Nijssen et al. (2001a) were calculated based on the 5-min Terrainbase Digital Elevation Model (Row et al., 1995), using the land surface mask from Graham et al. (1999). Soil textural information and soil bulk densities were obtained using the Soilprogram (Carter and Scholes, 1999) which combines the 5-min FAO-UNESCO digital soil map of the world (FAO 1995) with the WISE pedon database (Batjes, 1995). Soil characteristics, such as porosity and hydraulic conductivity were based on Cosby et al. (1984). Vegetation characteristics were specified using the AVHRR-based, 1-km, global land classification from Hansen et al. (2000).

3.3 Model Implementation

The VIC model was implemented for the global land areas (excluding Greenland and Antarctica) at a spatial resolution of 2.0^o and a daily time step for the period 1948 to 1998. The soil parameters that are currently used are based on the calibrated values derived in the global simulations of Nijssen et al. (2001b).

Eventually the model will be implemented at 0.5^o resolution and a sub-daily time step. A new set of soil parameters will also be derived for this proposed model simulation. Results from the recent World Meteorological Organization (WMO) Solid Precipitation Measurement Intercomparison will be used to correct for the wind-induced undercatch of solid precipitation. Corrections will also be made for liquid precipitation wind-induced undercatch and wetting losses. Underestimation of precipitation in mountainous regions will be corrected using a hydrologic water balance approach based on watershed runoff ratios and historical discharge data. Corrections will be determined by comparing the long-term annual mean of precipitation within the basin to the annual mean precipitation calculated by the annual runoff from that basin by the runoff ratio.

4. DISCUSSION

The summary results of the simulated land surface energy and water fluxes and states are presented here.

4.1. Snow Cover Extent

The observed snow cover extent from the NOAA-NESDIS/CPC weekly analysis (http://www.cpc.ncep.noaa.gov/data/snow) is compared

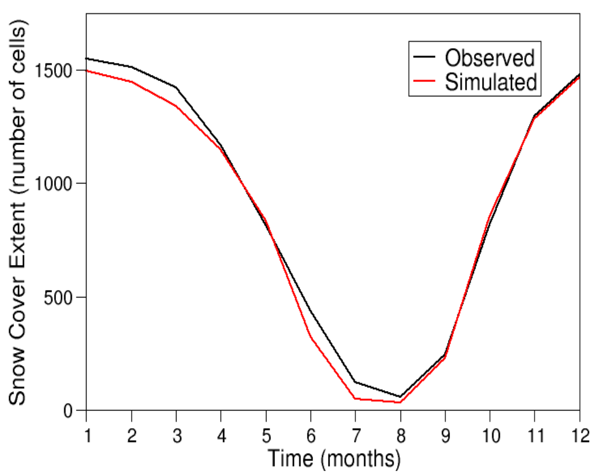

Figure 1: Comparison of VIC simulated snow cover extent (red) and observed snow cover extent (black) from NOAA-NESDIS/CPC. Units of snow cover extent are in terms of number of model grid cells.

with the VIC model simulated snow cover. The simulated snow covered area was defined as the area of those grid cells that had a mean snow water equivalent greater than 1 mm during a given month. In Figure 1, the number of grid cells with observed snow cover extent at 2^o in the Northern Hemisphere is compared with VIC simulated snow cover.

4.2. Soil Moisture Variability

Seasonal soil moisture patterns exhibit expected behavior with low moisture in the desert, and high moisture values in the humid tropics (see Figure 2). The drying of soils with the onset of summer in western United States and eastern Russia is quite evident. Soil moisture increases in South and Southeast Asia during the summer monsoon is also quite apparent. High soil moisture values can be seen in the humid Tropics, where high precipitation amounts keep the soil near or above field capacity during most seasons. The changes in soil moisture following the movement of ITCZ can be seen in Central and Southern Africa.

4.3. Evapotranspiration

Evaporation also shows expected regional patterns and seasonality (see Figure 3). Seasonal evapotranspiration is high throughout the year in the humid Tropics, where temperatures and precipitation amounts are high. Seasonal evapotranspiration is also high in eastern United States and Europe during the summer when the vegetation is fully developed. Low evaporation rates occur in moisture-limited environments, such as, the deserts of Northern and Southern Africa, the deserts of Central Asia and Australia, and the arid regions of southwestern United States and South America. Low evaporation rates also occur in energy limited environments, such as the middle and high Northern latitudes during the Northern Hemisphere autumn, winter and spring.

5. PROPOSED WORK

5.1 Validation

The VIC model simulated fluxes, especially of soil moisture and runoff, will be validated using available observations of these fluxes. The simulated soil moisture will be compared to observations of soil moisture available from the different datasets described by Robock et al. (2000). The runoff that is simulated at the grid cell scale will be fed into a simple routing model (Lohmann et al., 1996 and 1998) to generate timeseries of streamflow at various discharge measurement locations around the world, and will be compared with observed streamflow at these locations. Since runoff is parameterized in the VIC model, calibration of some model parameters might be necessary to give a good agreement between simulated and observed runoff. The identification of calibration parameters and the calibration procedure will be similar to that of Nijssen et al. (2001b).

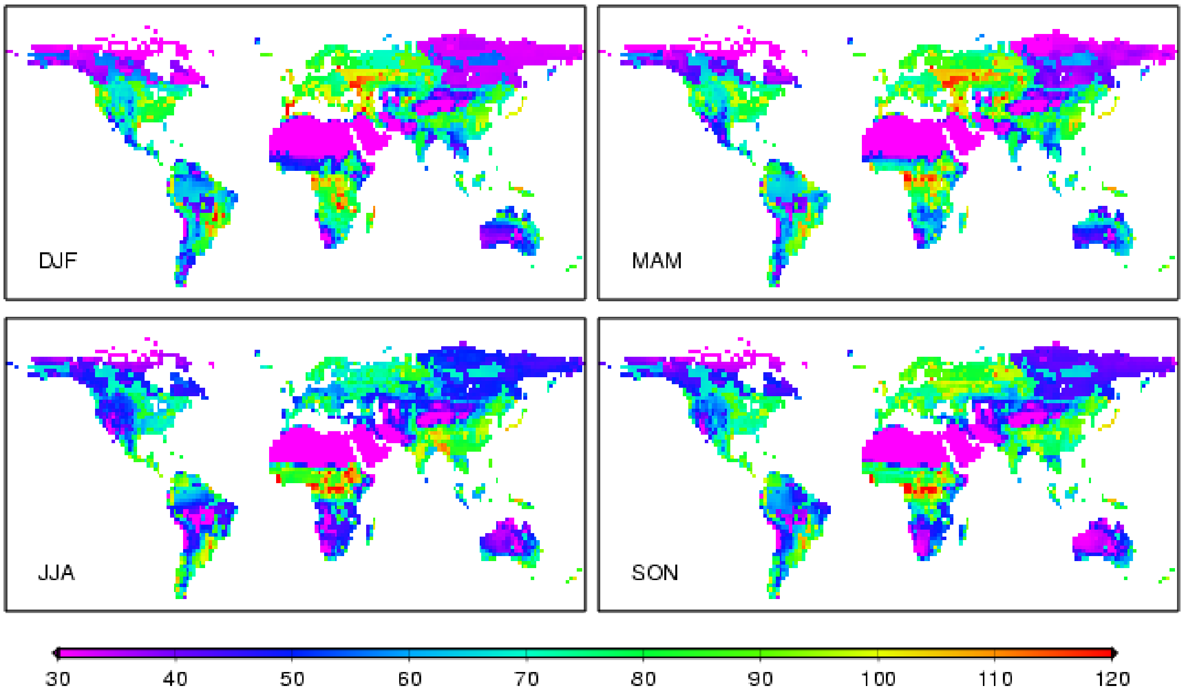

Figure 2: Seasonal Soil moisture (in mm) in the top 300 mm

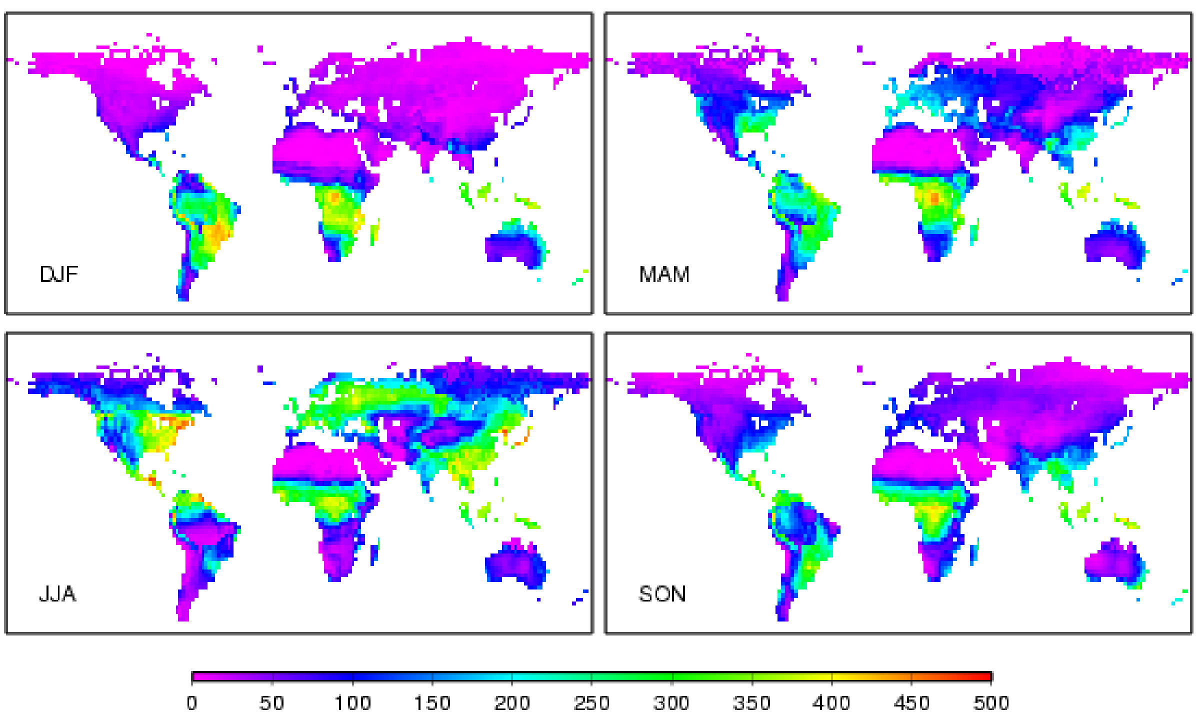

Figure 3: Mean seasonal evapotranspiration (mm)

5.2 Analyses

The simulated soil moisture states can be used to understand soil moisture variability, which can aid in soil moisture predictability useful in numerical weather prediction. The dataset can be used to analyze historic floods and droughts. Indicators of such hydrologic extremes can also be developed. The simulated hydrologic states can be used to examine their global teleconnections with ENSO, PDO, AO, etc. This dataset can also be used to analyze atmospheric and land surface water budgets.

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