Global ISLSCP Data Initiatives, and the Global Soil Wetness Project

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Introduction

The International Satellite Land Surface Climatology Project (ISLSCP) began more than a decade ago as an independent scientific initiative. The basic goals of ISLSCP have not changed: to improve our understanding of the physical and biological processes controlling exchanges of energy, heat and mass between the vegetated land surface and the atmosphere, and to utilize satellite remote sensing and other techniques to integrate our local-scale understanding up to regional and global scales.

The premiere effort was the First ISLSCP Field Experiment (FIFE; Sellers et al 1992, Hall and Sellers 1995) of 1986-1988, which established the principles for the successful conduct of multi-scale, multi-instrumented field campaigns that are still followed today. Since then, ISLSCP has become a component of the Global Energy and Water Cycle Experiment (GEWEX), and plays a leading role in two of the GEWEX regional experiments: the Boreal Ecosystem-Atmosphere Study (BOREAS; Sellers et al. 1995) and the Large-Scale Biosphere Atmosphere Experiment in Amazonia (LBA; Nobre et al. 1997).

In addition to regional field campaigns, ISLSCP has been at the forefront in the compilation and production of global terrestrial data sets. These are the products of the ISLSCP Initiatives I (Meeson et al. 1995, Sellers et al. 1996) and II (IGPO 1996), and the Global Soil Wetness Project (IGPO; 1995). In this paper, these global ISLSCP data products will be described, as will some of the recent results from GSWP that are relevant to issues of global land surface modeling and data assimilation.

Past ISLSCP Data Initiatives

The ISLSCP Initiative I produced a set of 5 CD-ROMs of global co-registered 1°×1° data over land grid points for the years 1987 and 1988 (Meeson et al. 1995). Updates and documentation have been posted on a web site accessible from the GEWEX and ISLSCP home pages. The data include monthly-mean vegetation parameters such as vegetation class, leaf area index, roughness length, albedo and fraction of photosynthetically active radiation absorbed by the canopy (FPAR). Soil parameters such as soil texture class, slope, soil albedo and depth to bedrock are also included. Also included are data sets on snow cover, soil moisture, net albedo and runoff.

In addition, near-surface meteorological data are included, based on ECMWF operational analyses, sometimes in combination with other observed data. Temperature, winds, humidity and pressure data are strictly from ECMWF operational analyses, and available as 6-hourly or monthly grids. Rainfall are based on the 24 hour global 2.5° monthly Global Precipitation Climatology Project (GPCP; WCRP 1990) analysis for 1987 and 1988 was the original source of the precipitation data. As with any analysis product, there is some uncertainty about the accuracy of the analysis, but the position of the project PIs was that the GPCP inaccuracies are significantly less than those of any GCM or 4DDA system to date. A 6-hourly temporal partitioning of the monthly GPCP precipitation was derived using the National Meteorological Center (now the National Centers for Environmental Prediction; NCEP) Reanalysis project data for 1987 and 1988. Both total and convective precipitation amounts were available. These were used to temporally partition the monthly GPCP amounts (see Mitchell and Lin 1994 for more information).

Monthly and global downward solar/terrestrial radiative fluxes at 2.5°×2.5° grids have been produced from International Satellite Cloud Climatology Project (ISCCP; Schiffer and Rossow 1985) products. They were

interpolated in space to 1°×1° grids. A similar procedure to that used for precipitation was used to divide up these fluxes into six-hourly downward shortwave and longwave radiation fluxes, based on ECMWF output.

By any measure, ISLSCP Initiative I has been a great success, and is among the top requested data sets from the NASA Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC). The user base for the data has been mainly within the various disciplines of earth system science research and education, but users from a much broader range of interests that was originally expected have made use of the CD-ROMs.

Future ISLSCP Data Initiatives

The major new initiative for comprehensive global land surface data is the ISLSCP Initiative II (IGPO 1996). As the name suggests, it is the successor to Initiative I, and should include data for at least a 12 year period (1986-1997) at a resolution of ½° resolution. Whereas the ISLSCP Initiative I was largely an effort to quickly compile the best data sets available at the time, Initiative II has been more carefully planned, and includes efforts by ISLSCP participants to foster and develop many of the new improved data sets. Lessons learned from Initiative I are being applied to improve the data, documentation and distribution.

In addition to improved data sets of vegetation (based on the global 1 km data set from the International Geosphere-Biosphere Programme; IGBP), soils, runoff, radiation, precipitation, snow and ice, ISLSCP plans to add global data sets on carbon (soil carbon and biomass), net primary production, and topography (including sub-grid statistical information). There are also plans to make available near surface meteorology on the same ½° grid at either 6 or 3 hourly intervals, interpolated from one of the major meteorological reanalysis products.

Regional data products may also be added, including data pertinent to major field campaigns, and data from the Fluxnet system of stations.

The media of distribution for such a large and comprehensive data set has not been finalized, although the Internet and specifically the World Wide Web will be an important component. It will almost certainly be impossible to place the entire set of near surface meteorology onto CD-ROMs, but probably the biogeophysical and biogeochemical data will be distributed on a multi-CD set.

Funding for ISLSCP Initiative II has been slow in coming, and the estimated release data for the data has been pushed back several times. At the time of this report, there is still no final confirmation of support from NASA. It is hoped that funding will be made available for fiscal year 1999, which should allow for a release date during calendar year 2000.

The Global Soil Wetness Project

One of the major users of the ISLSCP Initiative I data set has been the ISLSCP Global Soil Wetness Project (GSWP; IGPO 1995, Dirmeyer et al. 1998). Many hydrologically important quantities can be obtained from remote sensing or existing land-based observational networks. However, one of the most important, storage of water in the soil, is sparsely measured and not well known (Dirmeyer 1995).

The result of the limitations on observing soil wetness is that there has been no global time-varying data set of observed soil wetness. Historically, most attempts to create a climatology of soil wetness have used computational methods. A land surface parameterization (LSP) is used to calculate soil wetness S as an integral of the residual change in soil wetness in a simple water balance relationship:

$$S = S_0 + \int_0^T \Delta S dt$$

$$\Delta S = P - E - R$$

S_0 is the initial soil wetness, P is precipitation, E is evapotranspiration, and R is runoff.

All LSPs are computational models which simulate hydrologic, energetic, and chemical processes at or below the land-atmosphere interface using physically-based or statistical relationships established from experimentation in the laboratory and field. These LSPs are often components in larger hydrologic, biogeochemical, climate, or weather prediction models. The GSWP is an effort to produce a global data set of soil moisture, as well as surface fluxes and related components of the surface energy and water budget, for the two year period of the ISLSCP Initiative I data set. About a dozen different LSPs have participated, each using the ISLSCP parameters appropriate to the design of each model, and the near surface meteorological forcings provided on the CD-ROMs. In addition to this production group, there are also a Validation Group, and an Inter-Comparison Center.

Table 1. Participating LSPs in GSWP.

Center	Model	Investigator(s)
University of Arizona	BATS	Morrill, Dickinson, Hahmann
Center for Ocean-Land-Atmosphere Studies	SSiB	Dirmeyer, Zeng
Colorado State University	SiB2	Zhang, Dazlich, Randall
National Centers for Environmental Prediction	CAPS	Chen, Mitchell
GSFC - Climate and Radiation Branch	SSiB	Mocko, Sud, Walker
GSFC - Mesoscale Modeling Branch	PLACE	Boone, Wetzel
GSFC - Hydrology Branch	Mosaic	Koster, Suarez, Ducharne
Japan Meteorological Agency	JMA-SiB	Sato, Nishimura
Météo-France	ISBA	Douville, Noilhan
Macquarie University	BASE	Pitman, Zhao, Desborough
University of Tokyo - Center for Climate System Research	Bucket	Nishimura

The GSWP to date has been a pilot project, exploring the feasibility of producing and validating soil wetness and surface flux data on large scales. The concept and methodology are being proven viable, and the resulting data are useful. GSWP is not a narrowly targeted project, but attempts to address a number of issues. The goals are not merely to produce and validate global data sets of land surface hydrologic variables, but also to assess the feasibility of the processes of production and validation. Specifically, the goals of GSWP are:

- To generate global high-resolution data sets of soil moisture, runoff, surface fluxes, and associated hydroclimatologic quantities using state-of-the-art LSPs.
- To develop and test techniques for large-scale validation of hydrologic quantities over land.
- To apply and validate a large subset of the data from the ISLSCP Initiative I CD ROM.
- To compare a number of LSPs globally, and conduct sensitivity studies of specific components, parameterizations, and data considerations.

The following variables have been produced and saved by each model at 1° resolution three times per month. Some data are available as instantaneous values, and some are time means.

Table 2. Variables produced by participating LSPs.

Soil moisture (m)	Snowmelt rate	Sensible heat flux	Canopy water storage
Soil wetness (fraction)	Precipitation rate	Up, down shortwave	Soil layer wetness
Soil wetness index	Transpiration	Up, down longwave	Soil ice
Water in top meter of soil	Soil evaporation	Ground heat flux	Soil layer temperatures
Snow equivalent water	Interception loss	Canopy conductance	Snow temperature
Skin temperature	Snow evaporation	Aerodynamic resistance	Canopy temperature
Surface runoff	Total evapotranspiration	Surface stress	Ground cover temperature
Total runoff	Latent heat flux	Total soil energy	

Validation efforts in GSWP are showing that most LSPs behave remarkably similarly in simulating the annual cycle of the surface water budget, despite having very different mean values of soil moisture (Entin et al. 1998). Sensitivity studies have lead to improvements in the parameterizations of several LSPs. Parameter uncertainty and misrepresentation can greatly affect results. In the case of sub-grid scale heterogeneity, for example, Boone and Wetzel (1998) found that consideration of the sub-grid scale variability of soil properties such as saturated hydraulic conductivity, which are highly non-linear, can significantly increase simulated runoff.

A number of results are relevant to the collection and assimilation of data for weather and climate modeling. Oki et al. (1997) found a strong connection between the performance of the LSPs as a whole in simulating basin-scale annual runoff, and the density of rain gauges in the basin. They found that a minimum of 20-30 gauges per million square kilometers were necessary to minimize the error in modeled runoff. Douville et al. (1998) found that surface temperature and humidity can be assimilated to adjust soil moisture toward

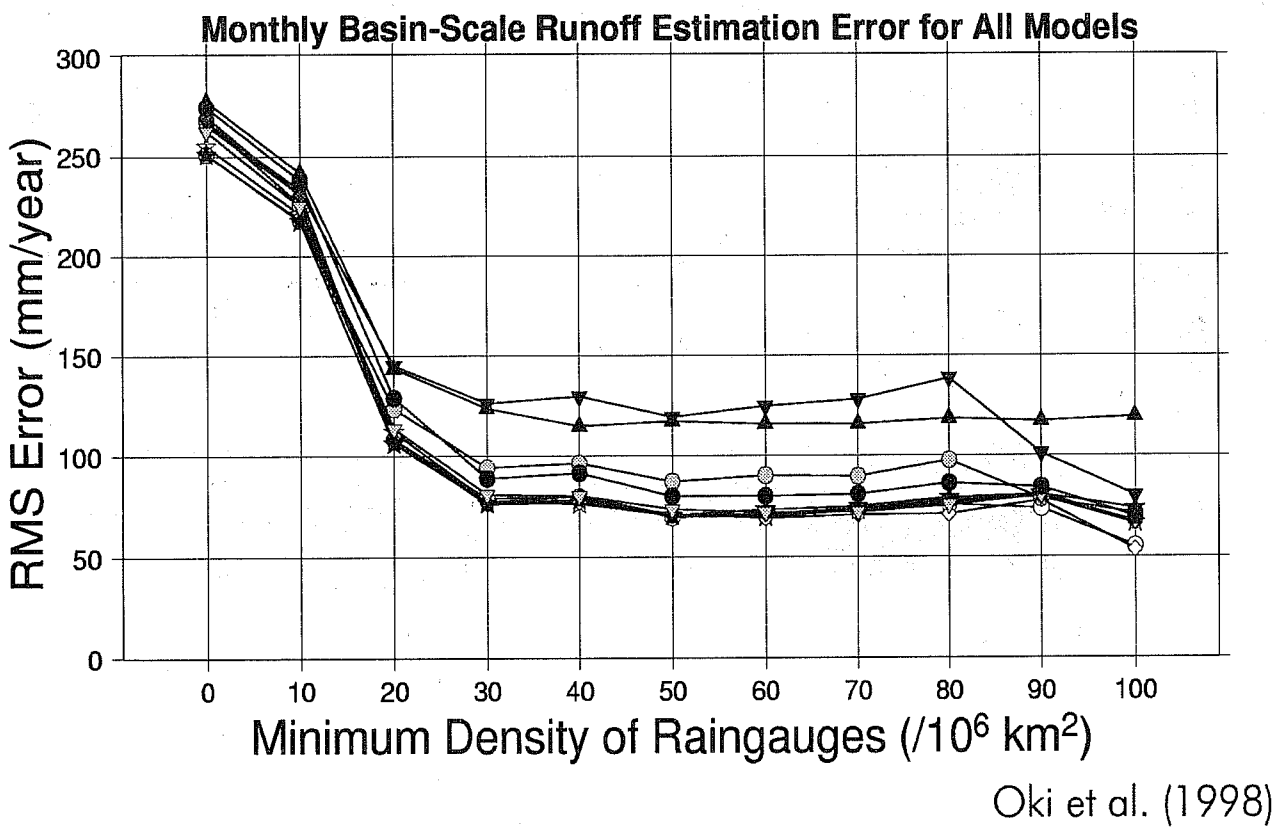

Figure 1. Error in the simulation of basin-scale yearly runoff as a function of the density of rain gauges whose observations went into producing the ISLSCP Initiative I precipitation data set.

analyzed values. But if analysis and observed conditions vary greatly, soil moisture will not converge to the same values. Dirmeyer (1998) found that the soil moisture data generated in the GSWP experiment, when used as prescribed boundary conditions, improved the simulation of patterns of summer season rainfall over land in a global climate model using the same LSP.

In a follow-on study to the original GSWP, the following question has been raised: To what accuracy must soil wetness be known in order to simulate observed fluxes to within observational accuracy? It was accepted, for the purposes of this experiment, that evaporative fraction (the ratio of latent heat flux to total turbulent surface heat fluxes) can be estimated to within 10% in field studies. The study employed three LSPs, BATS, SSiB and Mosaic. It has been found that the models generally agree in the spatial distribution of the sensitivity of fluxes to soil moisture. Greatest sensitivity is found in regions of sparse vegetation or bare soil. All three models are insensitive to variations in soil moisture in forested areas, except when the soil is particularly dry. It appears that in these models, transpiration is a relatively insensitive component whereas direct evaporation from the soil is highly variable with soil moisture.

A special issue of the Journal of the Meteorological Society of Japan presenting results from GSWP is being compiled. It should be published early in 1999. In addition, a GEWEX report is in the final draft stage, and an overview article based on the report will be published in the Bulletin of the American Meteorological Society (Dirmeyer et al. 1998).

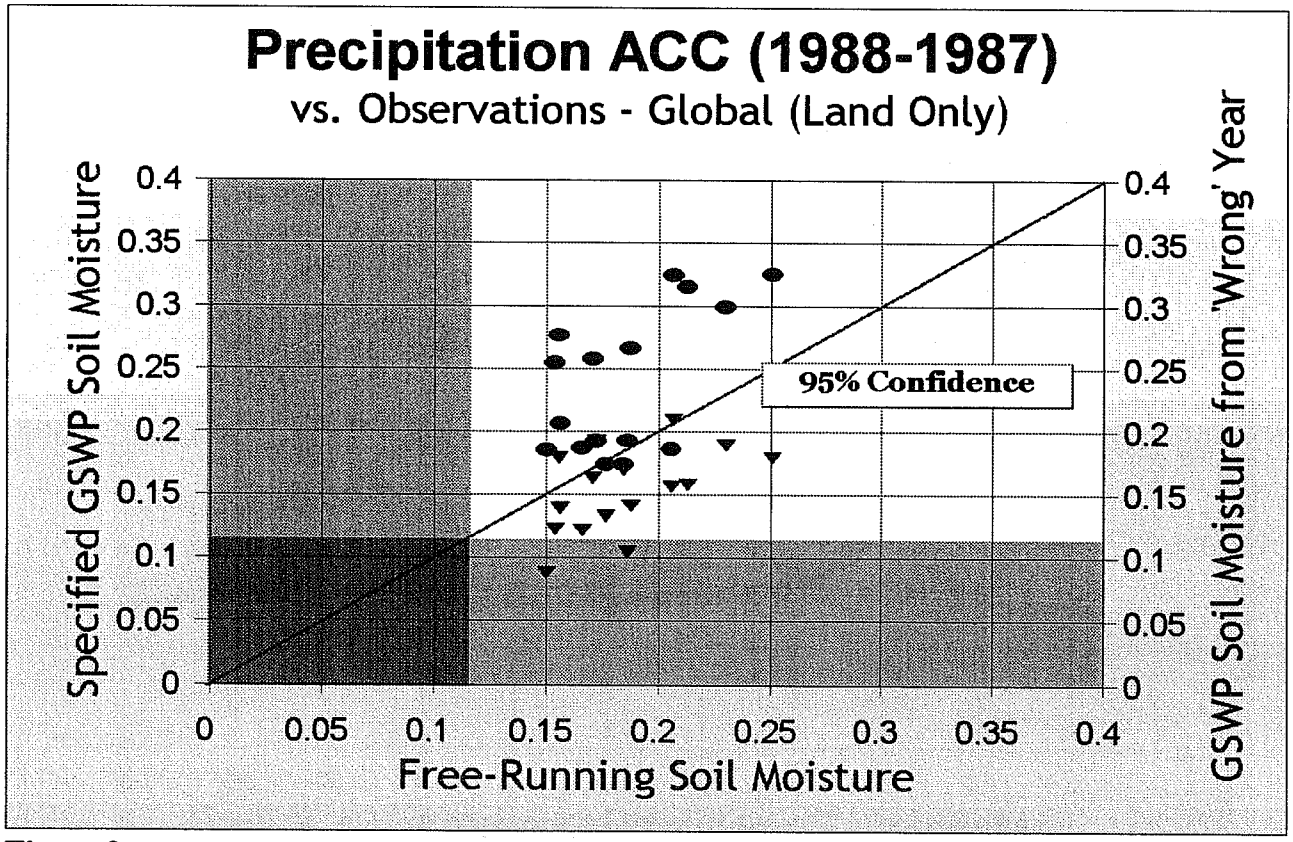

Figure 2. Comparison of anomaly correlation coefficients between all possible pairs of boreal summer 1988 minus 1987 precipitation anomalies from two ensembles of four integrations of the COLA GCM with SSiB. Circles compare integrations with specified GSWP soil moisture to fully interactive land surface - points above the diagonal indicate improved correlations. Triangles illustrate the degrading impact of specifying soil moisture from the opposite year.

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