Journal of Agrometeorology 3(1&2) : 319-326 (June-December 2001)

Summary and recommendations of the workshop on land surface process experiment over Sabarmati basin in India

P. S. N. SASTRY[1], P. S. RAO[2], V. PANDEY[3] AND A. M. SHEKH[3]

[1]17, Subrahmanya Nagar, Saidabad, Hyderabad-500 059.

[2]Earth System Science Division, Department of Science and Technology, Technology Bhawan, New Delhi-110 016.

[3]Department of Agricultural Meteorology, B.A. College of Agriculture, Gujarat Agricultural University, Anand-388010.

ABSTRACT

A summary of the papers presented at the workshop on "Preliminary Results of Land Surface Processes Experiment (LASPEX-97) over Sabarmati basin", held at Anand, Gujarat (India) during November 1999 is given. Recommendations and an outlook for future work are indicated.

Key words : LASPEX -97, Summary, Recommendations.

Land surface processes play a prominent role in exchange of momentum, heat, water vapour, carbon dioxide and other elements between the terrestrial ecosystem and the atmosphere surrounding it. Nature of land use is an important factor and seasonal influences such as those obtaining in the semi-arid regions of the Indian subcontinent provide a variety of situations. Hot summers, followed by monsoon rains, its aberrations like monsoon breaks, floods and droughts, its withdrawal and winter conditions visiting these regions, cropping systems and cropping pattern in the different seasons, soil type and distribution of water resources representing varied hydrological characteristics - all these present a challenge in determining and understanding the magnitude of the processes and the exchange coefficients involved. Boundary layer height variations, inversions, and other related thermodynamic processes are all affected by the nature of land surface processes, dynamic in nature. General circulation models (GCM) for prognostication of weather and climate are triggered by the thermal and moisture properties of the underlying land surface and its interaction with the atmosphere close to the ground, at macro, meso and micro scales. Understanding the nature of these ever changing dynamic processes under varying conditions of land use, soil and vegetation type and climate has been the objective of several land surface experiments carried out in the different nations.

The Department of Science and Technology (DST), Government of India constituted a task force during November 1992 under the Chairmanship of Dr. R.N. Keshavamurthy, Director, IITM (Indian Institute of Tropical Meteorology, Pune) to formulate a multi-institutional and multi-disciplinary research project on land surface processes (LSP) in the country. After due deliberations, during March 1994, the project proposal for undertaking the field experiment, land surface processes experiment (LASPEX) in the Sabarmati river basin in the Gujarat State was approved. The IITM and Gujarat Agricultural University (GAU, Anand campus) were identified as the lead institutions for project implementation. A Steering Committee, constituted under the Chairmanship of Prof. D.R. Sikka former Director, IITM (Also Chairman, Project Advisory and Monitoring Committee on MONTCLIM (Monsoon and Tropical Climate) and ICRP (Indian Climate Research Program), DST) provided the necessary scientific support in implementing the project.

A pilot experiment was organized at the nodal location, Anand during April-July 1995 as a precursor to the main experiment conducted at four more locations - Derol, Arnej, Sanand and Khandha during January 1997 to March 1998. Part of the program was extended until March 1999. Data on different components of micro-meteorological, hydrological and agricultural parameters were continuously monitored. Further, intensive observation periods (IOPs) of 5-day duration during 14-18 of every month were identified. Several scientists from IITM, GAU, India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF, New Delhi), Indian Institute of Technology (IIT, Delhi), Jawaharlal Nehru University (JNU, New Delhi), National Remote Sensing Agency (NRSA, Hyderabad), Space Application Centre (SAC, Ahmedabad) participated in the year long observational program. The GAU provided all the logistic facilities, and IITM provided the necessary technical support. IMD contributed in organizing special radiosonde and low-level pilot balloon ascents over the experimental region. Apart from funding the LASPEX project, DST sanctioned sub-projects to other scientific institutions in analysis and modeling aspects of the LASPEX data and also funded a science workshop.

LASPEX DATA BASE

Data were generated using a 30 m tower at Anand and 10 m towers at all the five stations (including Anand). Slow and fast response sensors were mounted on the towers. Data on soils, crops and weather, energy fluxes, upper air wind, and thermal structure, remote sensing observations during IOPs were monitored and collected. The atmospheric data were quality checked at the IITM, Pune and data for four representative months for the IOPs representing different seasons viz., summer and pre monsoon (May), southwest monsoon (July), monsoon withdrawal (September) and winter (December) were disseminated to the participating scientists for analysis. The results presented in this volume pertain to this database. All authors names mentioned are from the papers in this issue.

FIRST NATIONAL WORKSHOP ON LASPEX-97 - RESULTS

A national workshop on 'Preliminary Results of the Land Surface Processes Experiment (LASPEX-97) over the Sabarmati River Basin' was organized at the Department of Agricultural Meteorology, Gujarat Agricultural University, Anand campus from 18-20[th] November 1999. Fifty-seven research papers were presented and discussed by participants from 19 organizations / institutions in the country. The workshop consisted of seven technical sessions followed by a concluding session. A summary of the results and discussions, indicating authors' names, is as follows.

Land surface processes experiments - review and planning

At the outset, a review of previous international experience and status of LSP experiments were presented. The objectives of these experiments, instrumentation, organization of the technical program and results were briefly dealt with (Rao, Vernekar) and deliberated. These presentations formed the background view of the current status of the land surface process experiment projects conducted elsewhere in the world and also the experience gained through the MONTBLEX (Monsoon trough boundary layer experiment) program conducted in India in the year 1990. Need for improvements in the integration of land-hydrological-atmosphere interactions through modeling, problems associated with parameterization of exchange processes of water, energy, carbon dioxide and other gases under both homogenous and heterogeneous conditions of land use, and global scale modeling were mentioned. Spatially distributed information on the bio-geophysical properties and temporal changes of the terrestrial ecosystems as provided by satellite data, are additional inputs to investigate surface / atmosphere exchange processes. Inter institutional cooperation and coordination in implementation of such programs, development of numerical solutions, simulation of planetary boundary layer (PBL), use of satellite data in conjunction with land surface data sets, experience gained in model development, calibration and validation were mentioned. Development of algorithms for interpretation of satellite measurements of land surface features, interpretation and aggregation rules and their significance in modeling climate variability were also brought out.

The physiography, climate, soil characteristics, land use, agroclimatic features, cropping pattern of the experimental region which represented varying characteristics both in space and time had been dealt with in detail by Pandey, Kumar and Shekh. Specification of instruments, their heights of exposure along with periodicity of data acquisition and averaging intervals were summarized (Shekh, Vernekar and Keshvamurthy) which indicate the experimental set up both at the nodal station and other locations. Bare soil / grass cover in summer, sun hemp (a green manure crop) and groundnut crops provided the surface cover in the different seasons. Short and tall grass situations, differing vegetation cover in the representative months, which influence the atmospheric processes or flux rates were available during the course of the experiment near and in the surroundings of the tower sites. These conditions were considered ideal and unique for the LASPEX.

Radiation budget and impact of vegetation on surface boundary layer

Radiation and energy budget over bare and cropped surface, validation of a radiation parameterization scheme using LASPEX-97 data, diurnal variations, and residual energy flux over cropped surface formed the subject matter of this session. Studies on radiation profiles at 10 and 30 m tower sites at Anand location (Shekh, Kumar, Pandey and Gajjar) showed that net radiation was the lowest over bare soil in December (winter) and the highest over grass cover in May (summer). Changes in ground and sensible heat fluxes due to wet soil conditions (relatively higher soil heat flux) in July compared to May (pre-monsoon) were indicated (Murthy, Dharmraj and Pillai). Clay loam soils were found to have top dry layers and in loamy sand soils, top layer was comparatively wetter compared to the layers below indicating the different depths of moisture extraction (Patil, Parasnis and Vernekar).

Pollution and smog resulted in lower levels of short wave radiation (Kumar, Gupta, Shekh, Pandey and Patel). For validation of a radiation parameterization scheme, surface radiation fluxes prognosticated using NCMRWF operational model were compared with the flux observations (George). A first order weighting factor for temperature, introduction of a weighting factor for downward long wave radiation flux and introduction of dust particle aerosol in the NCMRWF model were found necessary.

Flux characteristics in the surface layer

Momentum and heat flux characteristics in relation to atmospheric stability, estimates using similarity theory were presented for discussion in this session. Maxima of momentum flux occurred at 1600 hrs. IST at the LASPEX sites (Patil, Murthy and Parasnis). Clay soil locations showed higher momentum flux compared to lower values at sites with loamy sand soil. With increasing atmospheric stability, there was a decrease in drag and heat exchange coefficient values. Variations in residual flux were related to plant (groundnut crop) height and biomass (Padmanabhamurty and Saxena). AE/PE ratio was parameterized with pan evaporation values for monsoon and non-monsoon months. Aerodynamic method resulted in higher residual flux values whereas Bowen ratio method gave relatively lower values. Polynomial relations were derived between residual fluxes and plant biomass at different growth phases of groundnut crop. Plant height gave a linear relationship with residual flux.

Momentum flux estimated by bulk aerodynamic method was lower than those measured by eddy correlation method (Shekh, Pandey, Kumar and Savani). Tower data and Sonic anemometer observations were used. Sensible heat flux showed an underestimate in summer (bare soil) and overestimates (under crop cover) during the rest of the seasons.

Boundary layer flux estimates within a 30 m layer above ground using Monin-Obukhov similarity theory at Anand (Singh, Simon and Joshi) for both stable and unstable conditions revealed presence of isolated sub layers rather than a constant surface during convective periods. Momentum flux decreased with increase in degree of stability in winter (December), and increased with increase in degree of stability in summer (May) and July (monsoon). Two factors noted in this connection were (a) similarity theory used potential temperature rather than virtual temperature (b) eddy correlation values were measured at one height where as similarity theory uses temperature structure of the entire surface layer.

Heat fluxes derived from two measuring systems at hourly intervals-capacity probe for relative humidity and sonic anemometer values at hourly intervals were compared at Anand (Sinha and Pillai). With relative humidity at 60%, the values showed agreement while deviations occurred above or below this value of relative humidity. Transition from one type to the other type of stability showed large deviation between observed and computed values.

Wind, surface processes and soil temperature

Relations between wind speed, frictional velocity, drag coefficient, wind direction for Anand location under sun hemp crop cover were presented (Kumar, Gupta, Pandey, Shekh and Parmar). Linear curve was fitted between drag coefficient and wind velocity. Drag coefficient increased with roughness length significantly in the monsoon withdrawal period. Impact of vegetative cover on the ejection and sweep processes in the atmospheric surface layer (Kulkarni and Sadani) showed variation in structural characteristics of intermittent ejection and sweep events with surface drag and atmospheric stability. Tall and short grasses introduced different type of drag conditions leading to roughness differences. Events, intermittent in nature, were found to depend on surface drag rather than on atmospheric stability. Rough surfaces introduced large intermittency in sweep and ejection process. Maximum contribution to the processes was from middle scale eddies.

Using 24-hour soil temperature values, at 5 cm depth at hourly interval, thermal properties of soil were computed (Sinha) to predict diurnal variations in land-surface temperature. A time-tendency term for surface temperature and a trigonometric (sine) forcing term as a function of damping depth were used in the expression. Artificial neural network technique was used to predict soil temperature at 0-5 cm depth using time and air temperature (George, Rammohan, Kulshrestha, Shekh and Jaita).

Remote sensing for estimation of soil moisture and surface fluxes

NIMBUS-7 SMMR data (May to July) of 1984 (good monsoon) and 1987 (drought year) were used to develop an algorithm for estimation of soil moisture (Rao, Thapliyal, Pal, Manikiam and Dwavedi) over the whole Indian region. Antecedent precipitation index and brightness temperature relation was used to represent soil moisture, assuming rainfall as a major forcing variable for soil wetness. SMMR data at 10GHz for H polarization was markedly sensitive to soil moisture variation.

Validation of roughness length, surface temperature, and sensible heat flux derived from remote sensing WiFS, NOAA, AVHRR data (Gupta, Prasad and Vijayan) were presented. Corrections were applied to AVHRR radiance values for sensor degradation, atmospheric scattering and scan angle effects before computing NDVI. Surface temperature, sensible heat flux from NOAA/AVHRR data matched closely with ground truth measurements during LASPEX. Results also showed that estimation of roughness length using NDVI is relevant for vegetated areas only. For bare soil, it was suggested that standard values or new methods - a NDVI based roughness value over non- urban areas may have to be devised.

Boundary layer modeling and surface fluxes

Boundary layer structure, modeling, parameterization of variables, and comparison with measured surface fluxes were the topics dealt with in this session. Assessment of the validity of the operational models in use at NCMRWF in estimating surface fluxes has been an important part of this exercise and is of operational significance.

Results from a single column LSP model and NCMRWF model showed under-prediction of temperatures and lower diurnal variation (Rajagopal). Soil temperature parameterization scheme needs modification. From results of comparison of two models, T-80 and T-126, Sanjay, Iyer and Singh suggested need for modification of the soil heat flux model as also the cumulus parameterization scheme as the present models gave underestimates of temperature and mixing ratio as also their diurnal variation. Simulation of planetary boundary layer (PBL) by ARPS (Advanced Regional Prediction System) in a 2-dimensional, non-hydrostatic meso-scale model was discussed by Das, Mohanty, Satyanarayana and Sarkar. Contrasts between summer and winter seasons were presented. Their results showed that the model has a tendency to keep a layer of maximum wind at the same height throughout the day both in summer and winter (May and December). Compared to other variables, in the different parameterization schemes, meridional wind seemed to be more affected. Inconsistency was noted in the individual estimates of surface fluxes. Model parameters in agreement and non-agreement with observations had been identified.

In a presentation by Parasnis, Kulkarni and Pillai, results from a one dimensional ABL model (a combination of a boundary layer model and a two layer soil model) gave variations in boundary layer height with the progress of the day and attainment of maximum height at 1300 hrs. Five-day forecasts generated using NCMRWF operational model (Basu) yielded underestimates of temperatures both in summer and monsoon (May and July) seasons, with overestimates in December. Closure and non-local closure (NLC) schemes were compared which showed comparatively better estimates of sensible heat flux with NLC scheme. Comparison of PBL structure between summer and monsoon seasons was discussed (Seetaramayya, Tyagi, Nagar and Murthy). Estimates of convective boundary layer (CBL) during monsoon were made (Murthy and Parasnis). Conserved variable analysis was followed in both these studies and thermodynamic classification of radiosonde data was done. Results indicated that (i) a three layer structure of sub-cloud, cloud and inversion of convective boundary layer was apparent (b) during monsoon season, both surface insolation and cloud processes together contribute to the growth of CBL (c) active monsoon period is associated with both shallow / deep convective activity and (d) CBL height is insensitive to local surface fluxes during monsoon season.

In a presentation of results on numerical simulation of seasonal variations of boundary layer at Anand location, using one dimensional PBL model with one and half TKE closure scheme (Satyanarayana, Mohanty, Lykossov and Sam), atmospheric boundary layer was partitioned into two sub domains; a near-surface constant flux layer and a free atmosphere top interfacial layer. Net radiation fluxes in summer and monsoon were overestimated while in other seasons, lesser deviation of estimates from measurements were obtained. High values of TKE were noticed in May, followed by July and December, and with lower magnitudes in September. In general, while both over and underestimates were obtained in summer and monsoon seasons, simulation of surface fluxes was relatively better in post monsoon and winter seasons.

In the overall discussion in the concluding session, it emerged that the objectives have been largely achieved and rich experience gained in planning, cooperation and coordination in implementation of the experimental program by the different participating scientists and institutions. Bottlenecks did exist in respect of instrument failure on occasions, and in obtaining continuous records. Quality check of data had given useful results, which are encouraging. Models and parameterization schemes do need modification, but it was possible through this experiment, where to look into, for this purpose. A point frequently mentioned in the discussion was that these are preliminary results from experimentation over a specific region for only representative IOPs, and the results should be taken as a guideline. When complete datasets are analysed, one could expect significant results to emerge providing an insight into the role of surface processes in triggering several variations in the boundary layer structure and, efforts in this direction should continue.

REMARKS AND RECOMMENDATIONS

Implementation of the LASPEX has provided a long felt opportunity for the participating scientists in the country to gain first hand experience in planning and conducting land surface process experiment with inter-institutional collaboration, maintenance and working of equipment, data acquisition, quality check procedures, data processing and analysis. This indigenous effort has placed India among other select nations, which had carried out large-scale observation programs related to land surface processes in the past decade and half.

Availability of human resources at different skill levels is very crucial for the successful conduct of such a distributed field experiment. Threadbare Management Plan with clearly defined contingency plans is crucial. A system analysis document of this experiment may be prepared for use in future experiments, to foresee any possible impediments for taking corrective action.

The project has yielded preliminary but useful results, which need to be consolidated and substantiated through experimentation for another 3 years in the same basin. Hydrological component has to be added in the technical program of future experiments of similar nature.

A comprehensive and composite picture of energy and water balance of the basins where LASPEX type experiments are to be undertaken is a prerequisite. Efforts have to be directed in preparing such a document through specified research programs.

Preliminary results presented at this workshop have repeatedly shown both overestimates and underestimates of the fluxes and boundary layer components. This calls for a close scrutiny of the assumptions and boundary conditions prescribed in the source codes of the boundary layer and general circulation models. Parameterization schemes need to be modified wherever necessary.

Availability of indigenously manufactured and calibrated sensors (wind, temperature, humidity, radiation etc.) used in micrometeorological studies in large numbers, continues to be a serious handicap in maintaining continuity of observations and avoiding gaps in data. Also for replicating such experiments at other locations with widely varying land use and climate situations, this has been a restraining factor, which needs to be corrected at the earliest. Large waiting time for sensor replacement leads to upsets in observation schedule and loss of crucial data.

Emphasis should be placed on linking the objectives and targeted results of similar experiments with remote sensing techniques. Support to more ground truth surveys, synchronizing and coordinating these, with intensive observation schedule is recommended.

Information on emissivity characteristics under varying land use and cropping patterns is meager. This gap has to be filled through systematic studies over several sites in the country.

In land use based experiments such as the LASPEX, efforts should be made to plan crop phenology based observations under cloudy, partly cloudy and clear sky conditions and build up response curves or functions. In addition to statistical analysis, use of dynamic simulation approach wherever applicable, is recommended.

Human resource development with emphasis on comprehensive interdisciplinary course contents in meteorology, physics, agriculture, statistics, instrumentation and remote sensing technology, etc., is very crucial for successful conduct of field projects like the LASPEX. Post-graduate teaching and training workshops in such interdisciplinary areas may be supported.

Organization and extension of LASPEX type of programs to new sites of synoptic weather significance and varied agricultural practices is recommended. The output from such programs, it is hoped would lead to improved prognosis of weather events and results of practical significance from general circulation models.

REFERENCES

Paper included in this issue, please see contents page.