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A brief review of observational net work for land surface processes studies

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ABSTRACT

In the last decade the land surface processes studies have gained lot of importance and in this connection many field programmes have been undertaken by many countries elsewhere. To carry out these land surface processes (LSP) field programmes it is essential to have appropriate observational network. These aspects are briefly reviewed with respect to earlier LSP experiments viz., HAPEX-MOBILHY, FIFE,EFEDA, and HEIFE programme.

Key words : Land surface process, HAPEX - MOBILHY, FILE, EFEDA

The coupling of the land surface processes with the overlying atmosphere takes place through the eddy exchange of heat, momentum and moisture. Thus, it has become important to know about these exchange processes between land and upper layers of the atmosphere. World Climate Research Programme (WCRP) aims at the improvement of our knowledge of the climate system with a view to predict climate change on different time scales. Research planned under other international programmes e.g. International Geosphere - Biosphere Programme (IGBP), Global Energy and Water Cycle Experiment (GEWEX) also have a bearing on the study of land surface process. Recently, India has undertaken a land surface processes experimental study in the Sabarmati river basin. In this context it is profitable to know about the organization of land surface processes experiments conducted elsewhere. Some of the experiments are briefly outlined in the following sections.

Since 1967, many boundary layer experiments like WANGARA, KANSAS, PHOENIX, GALE, HAPEX, HEXOS, FIFE, EFEDA, have been conducted with various objectives relating to land surface processes. They have a common objective of studying the fluxes and their parameterization required for the development of GCMs. In this paper a brief outline of the field experiments HAPEX-MOBILHY, FIFE, EFEDA, HEIFE is done. The sites, objectives, instrumentation and highlights of these experiments are briefly mentioned.

HAPEX MOBILHY EXPERIMENT

Objectives

1. Improvement of current knowledge of surface hydrology on scales running from few meters to tens of kms.
2. Measurement of evaporation by several independent methods and at several points.
3. Testing of parameterisation used in climatic models to specify the

evaporation, soil moisture and runoff components.

4. Contributing to interpretation of remote sensing data by providing the ground truth.

Preparations for HAPEX MOBILHY started in 1983 at national level and at the international level under the sponsorship of WCRP. The programme started in mid 1985 and lasted for 18 months. The data processing was completed in 1989. (Andre *et.al.*, 1986)

Experimental Site

The selected site for the experiment was a square (100 km^2) area in the southwest France, falling under the basins of Adour and Leyre rivers. It is divided into two fairly homogeneous regions and avoids the coastal zone as well as mountain terrain of the nearby Pyrenean mountain but with a significant climatic variability. In particular potential evapotranspiration varies significantly within the area as does the precipitation / evaporation ratio ranging from 1.4 in the extreme south of area to 1.0 in the north.

Surface network

The surface network was meant to provide the data input for the estimation of evapotranspiration by different independent methods needed for validating and calibrating satellite measurements. Two weather stations within and four at the corners of the experimental area were established and following parameters were measured.

i) Air and dew point temperatures at screen height.

ii) Temperature at various levels above the surface and below the surface iii) Wind at 10m

iv) Precipitation rate

v) Evaporation

vi) Solar and terrestrial radiation.

Additional stations were established in the experimental area where in arrangement were made for measurement of rainfall at 59 sites, maximum and minimum comparition at 35 points, humidity at 20 points, evaporation at 16 places, river and stream gauging at 33 sites.

Special observations were arranged for two upper air soundings at synoptic hours at Bordeaux and Radars at Bordeaux and Toulouse to provide precipitation patterns.

Measurement over forest area

Portable masts were erected one in the western part and second in the eastern part. On one mast a Gill anemometer and a Carbon humidity sensor were deployed to get carbon fluxes and on the other, Sonic and Gill anemometers and an infrared hygrometer were exposed.

Aircraft Observations

KingAircraft (NCAR) was deployed to measure moisture, velocity covariances and C-130 Aircraft (NASA) was deployed to measure water and heat fluxes and provide ground truth to the satellite observation periods (SOP). Aircraft observations were conducted during SOP to design an optimal aggregation scheme based on flight data obtained between and above the surface network stations and to provide a direct estimation of total evaporation during climatologically significant

period .

Result highlights

1) A new method of parameterization for land surface processes that is simpler than most of previous methods were developed with a capacity to reproduce correctly the energy budget at the local scales.

2) From the aircraft observations it was concluded that the inversion layer entrainment of heat/ moisture takes place due to upward moving moist convective cells.

3) For the first time it was reported that Sonic anemometer measurements might cause flow distortions and may introduce a mean vertical velocity error.

4) A two layer model using sensible heat flow was developed to estimate daytime integrated evaporation

5) The fluxes of heat and water vapour can vary significantly with height leading to large deviations from the Monin Obukhov Similarity theory, which can be applied in certain cases over non-uniform terrain.

6) The satellite derived estimates and surface evaporation were successfully used for estimating evapotranspiration.

FIRST ISLSCP FIELD EXPERIMENT (FIFE)

The First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE) was initiated in 1983 (FIFE, 1992) to address two drawbacks of the previous methods. i) Existing climate models contained poor representation of the processes controlling the exchange of energy, water, heat between land and atmosphere. ii) Satellite remote sensing had been under utilized as a means of specifying global fields of the governing biophysical parameters.

objectives

1. Improved understanding of the exchange between the land surface and the atmosphere at the local scale (1 - 100m)

2. Application of remote sensing science at the local scale (1 - 100m)

3. Use of remote sensing and models to describe surface atmosphere exchanges at intermediate scales (100m - 15km)

4. Improvement of measurement capabilities and experimental techniques.

Experimental Site

The site chosen was 15x15 km^2 area covered by tallgrass praire, surrounded by agricultural land near Manhatten in the central Kansas state U S A. The FIFE site was primarily dictated by the airborne flux measurements and the spatial resolution of the polar orbiting satellites. Topography was complex with gently rolling hills with several distinct drainages.

Instrumentation

Eight portable automatic stations, 4 super automatic weather statiuons, 14 Bowen ratio systems, 6 eddy correlation equipment, were deployed over the experimental area. Two Doppler Lidars were also used. Extensive rawinsonde launches were carried out during the experimental phase. A total of 5 aircrafts were used under FIFE programme ; NASA -

C - 130, NCAR King Air, NAE ,Canada Twin Otter, NASA H-1 Helicopter, NOAA - Aerocommander. Using these, three Co-ordinated Mission Plans (CMP) were executed.

Satellite observations

GOES provided half hourly, visible and thermal data useful for surface and atmosphere radiation studies. NOAA polar satellites passed over the site twice a day and provided visible, near visible and thermal data at 1-2 km resolution. LANDSAT, SPOT, KOSMOS 1939 - satellites provided high resolution frames (few tens of meters) in the visible and near infrared bands.

Result highlights

Where instantaneous estimates of evaporation values are available, it is possible to infer its diurnal variation from the known variation of other components of the surface energy budget by assuming "self preservation" in the diurnal evolution of this budget. Lidar data could be utilized to calculate the area averaged vertical profiles of horizontal velocity by volume imaging and in evaluation of fluxes $u'w'$, third moments of w' and kinetic energy. Flux measurements made by aircraft and surface stations were shown to be in good agreement. Intercomparison of fluxes derived from various aircraft was in good agreement.

The problem of horizontal advection and simultaneous determination of vertical flux gradients has been solved using data from two aircraft flying at two different heights. These experiments have enabled determination of

(a) seasonal variation of canopy photosynthesis, PAR, leaf water potential,

(b) domparison of surface reflectance derived from satellite

(c) active and passive microwave measurements of soil moisture and

(d) computation surface energy balance by remote sensing technique.

EUROPEAN FIELD EXPERIMENT IN DESERTIFICATION THREATENED AREAS (EFEDA)

The EFEDA Project (Bolle *et al.*, 1993) was implemented to study the land surface processes and their dependence on the sub surface water regime in the course of an aridification process. One main objective was to test and improve mathematical models describing the interaction between the surface and the atmosphere on a horizontal scale of about 100 km.

objectives

(i) Interrelationship of sub surface water fluxes, water transfer in soils, and impact of water use on ground water as well as latent heat fluxes

(ii) Coupling between land surface and atmosphere by exchange of energy, heat, momentum, moisture and by other substances, such as carbon dioxide and particulate matter.

Experimental site

EFEDA experimental site (100 km^2) was located on the upper part of the Guadiana river basin in the Mediterranean region. In this basin Castilla-la Manch is relatively flat

which is compatible with the grid mesh of global models. Three sites arranged in a triangle at a mutual distance of about 70 km were chosen covering dry farming (Tomelloso area), irrigated farming (Barrax area) and vegetated area (Rada de Haro area - Belmonte) regions.

Instrumentation

The entire instrumentation was done by different universities / institutes. Eddy correlation, profile, variance and scintillation methods, soil heat plates and caloric method measurements were done by the Dept of Meteorology, Wageningen Agricultural University.

At Rada de Haro (Belmonte) 5 sites, the instruemnt were monitored by Free University of Berlin. The following instrumentation was done where in a 12 m mast was equipped with anemometers and psychrometers at 5 levels. Measurement of soil temperature and soil heat flux up to 40 cm depth, radiation flux, PAR, Sonic anemometer at 3 m, were taken. Two sites (i) Rada de Haro; and ii) Tomelloso monitored by University of Copenhagen were equipped with the following instrumentation.

Anemometers at 1, 2, 3 and 5 m, thermometers at 1 and 3 m, hygrometer at 2 and 5 m, flux plates at 5 and 10 cm depth, soil Temperature up to 40 cm depth, Gill sonic anemometer and a Krypton hygrometer.

Six sites (five at Tomelloso and one at Barrax) were chosen by Centre National de Recherches Meteorologiques (CNRM) to monitor the observational net work under EFEDA. Radiosondes - every two hours, wind speed at 10 m, air temperature and specific humidity at 2 m, air pressure, radiation components, rainfall, soil heat flux at 5 cm, soil temperature at 5 cm measurments were taken.

Observations over vegetated areas were taken by Institute of hydrology Wallingford & University of Reading. Advection studies were done by INRA Centre de Recherches, by using net radiation, temperature and humidity sensors over the crops. A Sonic anemometer was also exposed.

Result highlights

Hydrological models were developed to simulate the transfer from the precipitation areas to the exploitation area. A database of soil characteristics was established. Spectral characteristics of vegetation, grapevine, oak tree forests and semi natural mottoral vegetation were determined. Surface fluxes were evaluated using different techniques. Simultaneous observations from aircraft, radiosondes and surface allowed studying the interaction of the surface processes with the meso and large-scale atmospheric circulation. Maximum humidity was observed around 4 km. The troposphere often showed complicated structures indicating several layers with different moisture contents. Long term AVHRR data series on the constant flat surface made it feasible to analyze aspect angle effect.

HEIFE PROGRAMME

This project was undertaken jointly by Japan and China during the period : Oct 1990-end 1991.

Objectives

1. To improve the understanding of land surface processes on scales ranging from a few kilometers to 100 km.

2. Test the parametric formulations of evaporation, ground water and runoff used in the climatic models.

3. Provide a meaningful physical basis for developing and testing new conceptual models of surface hydrological processes.

4. Validation of satellite data with ground observations.

Other objectives

Observations of the boundary layer - Turbulence fluxes, structure of PBL and local circulation. Observational study of radiation - Radiation budget, aerosols and their influence on radiative transfer, ground truth of satellite data, Tropospheric Ozone and CO_2. Observation of water budget - Fluxes over plains and over desert, Lysimeter observations of evapotranspiration. Rainfall. Establishment of a database. Numerical modelling of boundary layer. Hydrological approach to problems of water resources in Heife river basin.

Experimental site

Mainly consisted of a large area of Gobi and other deserts with a few Oasis along the river Heife. (Total area 9280 square km) Depending upon water conditions, the experimental area is divided into four regions (i) Oasis (wetland) (ii) Desert (iii) Gobi (iv) Hilly area.

Annual precipitation of Heife experimental region is < 200 mm. It is a transitional region between mountain climate and extreme arid climate. Five flux stations - Two in Oasis (Zhangye and Linze), One in Desert (Yingongcheng desert), One in Gobi (Huayin Gobi), One in inter-facial area between desert and oasis - (Pingchaun).

Instrumentation

A total of 5 towers (two by Japan and three by China) of 20 meter height were erected.Instrumentation on the towers was comprised of wind speed (0.5, 1, 2, 4, 8 & 20m), temperature (1, 2, 4, 8 & 20m), wind direction (1, 4 & 20m), humidity (1, 2, 4, 8 & 20m), radiometer (20m), pressure, soil temperature (-.05, -0.1, -0.2, -0.4, - 0.8, -1.6 m), precipitation, soil moisture (- 0.1, -0.2, - 0.4, -1.6 m), soil heat flux (- 0.1m).

Atmospheric turbidity (using Sunphotometer), atmospheric dust particle counter, and atmospheric ozone concentration measurment were done at Zhangye station. Measurments by lysimeter (1 Oasis station) tethered balloons (3 stations), Doppler Sodar (1 station), Low level sounding (4 stations), Sonic anemometer (4 stations), Lidar (1 station), Aerosol sounder (1 station).

Radiation system included short wave incoming and reflected radiation, infrared incoming and outgoing, surface radiation temperature. Rain gauges at 24 stations and hydrological stations 4, runoff and 73 wells for water level were also installed.

Result highlights

(i) A 3D mesoscale numerical model which included the turbulent kinetic energy equation and K - E closure term has been improved and further verified by HEIFE data.

(ii) Comparing the water vapour flux calculated from diffusion transfer models with the observed evaporation value, it was concluded that lowering of vapour

density due to salinization played an important role in vapour transfer.

(iii) Soil movements in the oasis area monitored by pressure heads using tensitometers. (iv) Water budget study in the Tangula Mountain area in the Tibetean plateau.

(v) The turbulent K.E. budget and temperature variance budget were compared by using spectral density dissipation and eddy correlation techniques. Both were in good agreement. (vi) Negative sensible flux during day time was observed on many occasions near the Oasis region.

(vii) Validation of surface albedo detected by satellites and surface observed albedo. Experimental study on the energy balance and CO_2 flux over wheat near the Oasis.

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