International Conference on Water Problems in the Mediterranean Countries

PROCEEDINGS

17-21 November 1997

TU-REMOSENS PROJECT AND DEVELOPMENT OF AN INFRASTRUCTURE TO OBSERVE THE WATER POTENTIAL IN AN UPPER CATCHMENT OF EUPHRATES

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INTRODUCTION

The main objective of the TU-REMOSENS project sponsored by NATO Science for Stability (NATO-SfS) program was to create an infrastructure that will be able to automatically detect areal snow cover by satellite techniques using NOAA /AVHRR sensor and to create operational models based on snow date transferred automatically via ARGOS transmitter using some special sensors. It was also aimed to establish data bank computer storage on the archived data for snow measurement to design and operate water resources systems (dams, reservoirs) , so that the analysis of real time data will provide forecasting of runoff in order to enable managers to make decisions with high quality scientific data . The project also aimed to run recently developed / upgraded snowmelt runoff models for their comparison with the observed records.
The tasks to accomplish the major objectives can be listed as:
1 - The installation a real time NOAA / AVHRR receiving station (accomplished)
2 - A data archive and retrieval system for areal coverage of snow (started)
3 - An integrated system to analyse the snow cover variation and to investigate on the estimation of snowmelt by runoff models (under investigation)
4 - An operational ETA Step Mountain model for the prediction and deposition of dust transport originating from desert regions (started) .
The project named TU-REMOSENS officially approved last year, in August 1996, by all the partners (METU, BILTEN, TUBITAK and NATO) and the funds was made available in September 1996.

IMPORTANCE OF THE PROJECT

The importance of global climatic issues due to increase in greenhouse gas emissions is a great concern and effects many nations in many aspects and associated environmental problems are potential security risk. On a regional basis the increase hydroelectric and agricultural demands on Tigress and Euphrates runoff greatly affect the political and economic stability of the Middle East where struggle for water has become the focus of international concern. Thus, better management of the water resources is of great concern and at present the boundary limits for the water resources starts from highlands of the Eastern Anatolia. The aim of the present study is to demonstrate the use of modern technology for development of a scientifically sound database. In addition, the implementation of the appropriate models that can be handled for the estimation of snow water equivalence will be of out most importance. The seasonal runoff estimation from snow melting is extremely important in mountainous areas, such as the eastern part of Turkey, where most of the water originate from upper elevations and contribute to the dams located on Euphrates River (Keban, Karakaya and Atatürk dams). Therefore , early forecasting of melting runoff in advance of time provides various advantages in early planning and operation of water resources systems .

One of the best applications of the (RS) technology is to observe and detect the variations in snow cover over vast regions. This techniques is very well known and applied in developed nations but not in developing nations , and Turkey was a typical example of such nations. This has highlighted the importance of using RS / Geographic Information System (GIS) data for utilising the water resources potential in an optimum manner . The high plateaus of Eastern Turkey (Euphrates River) offers an ideal location for the applications of such new techniques as illustrated in Figure 1.
The RS , when coupled with the GIS , as input to prediction models has the ability to produce simulated data , which can be compared with actual measurements . Since large dams are located in this region , their optimum operation and flood control depends on the reliable estimation of floods in early spring months (April - June), during which 65 - 70 % of the total annual flow is contributed.

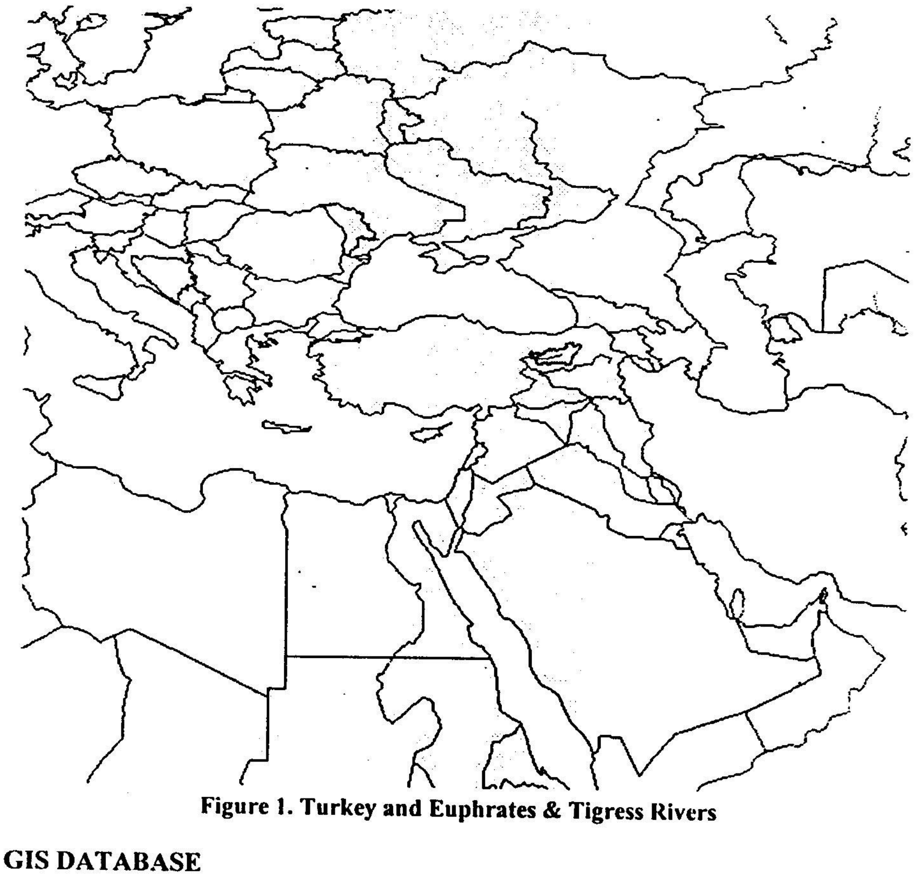

Figure 1. Turkey and Euphrates & Tigress Rivers

GIS DATABASE

Ground observations of snow depth , density and water equivalent are the primary data source for the calibration of the snowmelt runoff models. The runoff measurements collected at several gauges provide the database for the actual hydrologic information during snowmelt conditions that can be tied to the point observations of snow depth. On the other hand topography , vegetation and land use information from other data sources assembled in GIS will aid estimating the snow depth variation at a basin scale.

Topographic components of the database include elevation , slope , aspect , basin boundaries and river networks. As an example elevation map of Karasu basin is illustrated in Figure 2. The topographic components are extracted using a digital elevation model (DEM) of the Karasu River basin. The DEM for the Karasu River and its tributary were produced by digitising the topographic map of the area at 50 m. contour interva s. After that using statistical techniques quantitative analyses are done such as area-elevation curve analysis , slope - aspect analysis as well as slope-exposure analysis. The results of slope and aspect analyses are taken into account in the snow line assessment in order to separate snow line-altitude for different aspects.

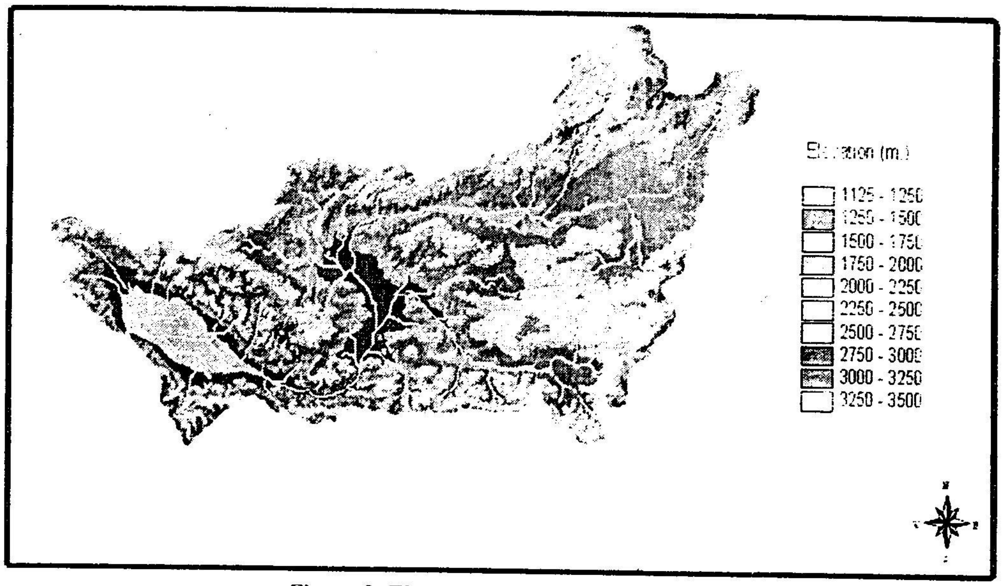

Figure 2. Elevation map of Karasu Basin

PROCESSING & ANALYSIS OF NOAA/AVHRR DATA

The raw NOAA/AVHRR images are collected from the ground receiving station at the RS/GIS Centre (BILTEN-TUBITAK) . Using a software this raw image is converted to LEVEL1B format and then it is imported to an image processing program named PCI. The 5 spectral bands (each being 10 bit data) are calibrated by ratio of radiance and temperature . Orbital model parameters are used for radiometric and geometric corrections. Geo-coding is done for fine geo-referencing of images so that accurate registration (less than 1 pixel) can be achieved on the National Grid Coordinate System (UTM). These processing steps are shown at Table 1. As an example an image of March 29,1997 is shown in Figure 3.

Since the NOAA/AVHRR satellite images are the primary data source in this project which are ideal in time and spatial resolution , visually fog-free and cloud-free days are selected initially for the last winter period since the recording started for the analysis.

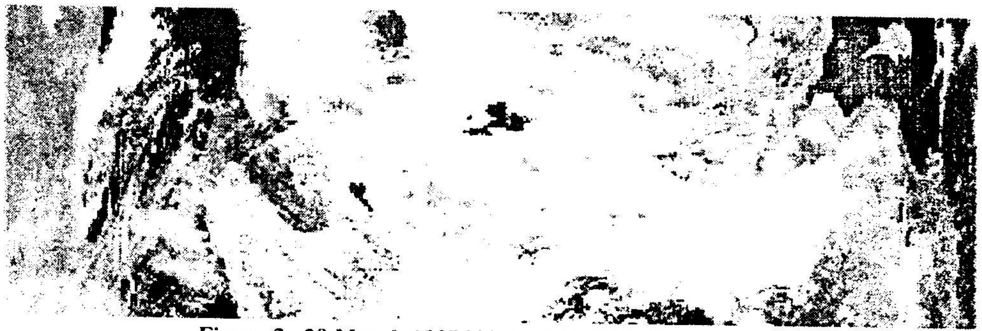

Figure 3. 29 March 1997 NOAA-14/AVHRR raw image

These satellite images are classified using the best band combinations as false colour composite (see Figure 4). Band 1 is selected for snow pack and bands 3 and 4 are for snow/cloud discrimination. Iterative Self Organising Data Analysis (ISODATA) is performed to assign cluster for each pixel brightness value using minimum spectral distance algorithm .

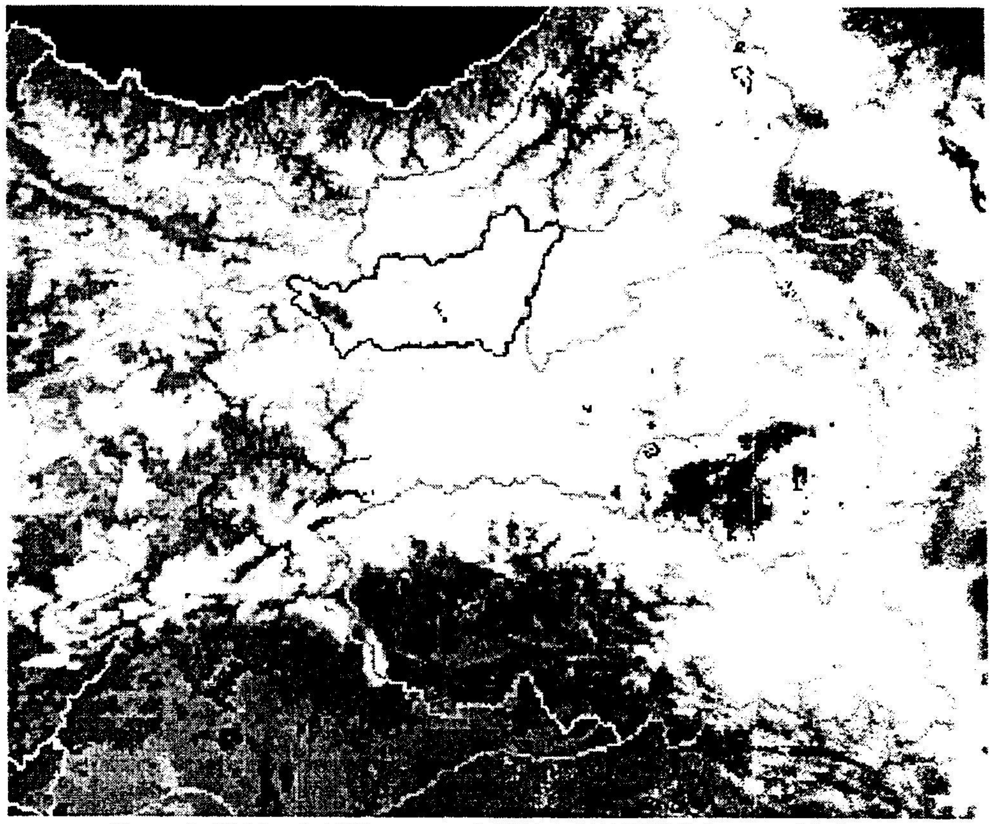

Figure 4. 29 March 1997 corrected NOAA-14/AVHRR image with basin and lake boundaries and coastlines

This type of statistical classification technique is important to achieve good accuracy for the project objectives. Further classification like maximum likelihood classification will be done in order to distinguish snow from cloud and to assign spectral signature for each cluster such as water, land , snow , cloud coverage .

Colour composite maps of the AVHRR scenes are used to determine the snow depth and areal snow coverage especially on the top of escarpments in conjunction with the basin boundary and topographic contours above a selected altitude. Data is collected from the snow measuring stations and compared with the AVHRR image values. It seems that the clustering of snow depth for band 1 is possible and effective using RS/GIS techniques.

A relationship can be established mathematically between snow depth and satellite brightness temperature. The percent distribution of frequency histogram for reflectance can be more effectively used for clustering . But because of lack of sufficient ground survey data done manually so far , no attempt has been made at this stage for assignment of snow depth.

The georeferenced images will be used only for the determination of spatial coverage of snow at different time scale . When more ground truth data of snow depth and snow water equivalence become available by the new electronically gauged snow stations , there will be an easier and mathematically sound relationship between depth of snow and brightness reflectance values.

OTHER SATELLITE DATA (DMSP/SSMI) FOR IMAGE INTERPRETATION

It won't be sufficient to threshold the visible band of AVHRR image alone for the depth categorisation and the areal snow coverage of snow especially under cloudy / partial cloudy days. For accurate estimation it is extremely important to take into account other spectral bands such as 3 & 4 as well as some other satellite information such as special sensor of microwave frequencies (SSM/I) of the Defence Meteorological Satellite Program (DMSP) which overpasses twice daily (ascending and descending) on an orbit at a certain altitude. It has a coarser spatial resolution but it is not affected by the cloud formations. Therefore , they are known to be most useful images for evaluation of dry and deep snow even under cloud coverage. For the elimination of the atmospheric constrains on the use of AVHRR , a passive microwave method is expected to be very useful for snow monitoring. Therefore , the

Table 1. Processing steps of raw image data for integration with the hydrologic models

1. Image Restoration
    - 1.1. Radiometric Correction
    - 1.2. Geometric Correction
    - 1.3. Removal of Noises
2. Image Enhancement
    - 2.1. Image Reduction
    - 2.2. Image Magnification
    - 2.3. Contrast Enhancement (Linear , non-linear)
    - 2.4. Band Rationing
    - 2.5. Filtering (Spatial convolution filtering ,high frequency filtering , edge enhancement)
    - 2.6. Special Transformations (Principal components analysis , canonical analysis)
3. Image Classification
    - 3.1. Statistical Methods
    - 3.1.1 Supervised Classification
        - 3.1.1.1 Training Stage
        - 3.1.1.2 Classification Stage
        - 3.1.1.3 Output Stage
    - 3.1.2 Unsupervised Classification
    - 3.1.3 Fuzzy Classification
    - 3.2. Physical Methods
    - 3.3. Visual Inspection
4. Integration of satellite image (RS) with Geographic Information Systems (GIS) and data extraction from database (DEM).
5. Execution of the hydrologic model with the extracted data

research team is in contact with the Global Hydrology Resource Centre at NASA in order to get some of the recent images for a small charge for the analysis of snow monitoring.

Current research is now underway by the team members to focus on the various algorithms to use AVHRR+GIS plus SSM/I data together. Integration of NOAA images with SSM/I data will be accomplished as a next step for their coupling with the snow melt models (see Figure 5).

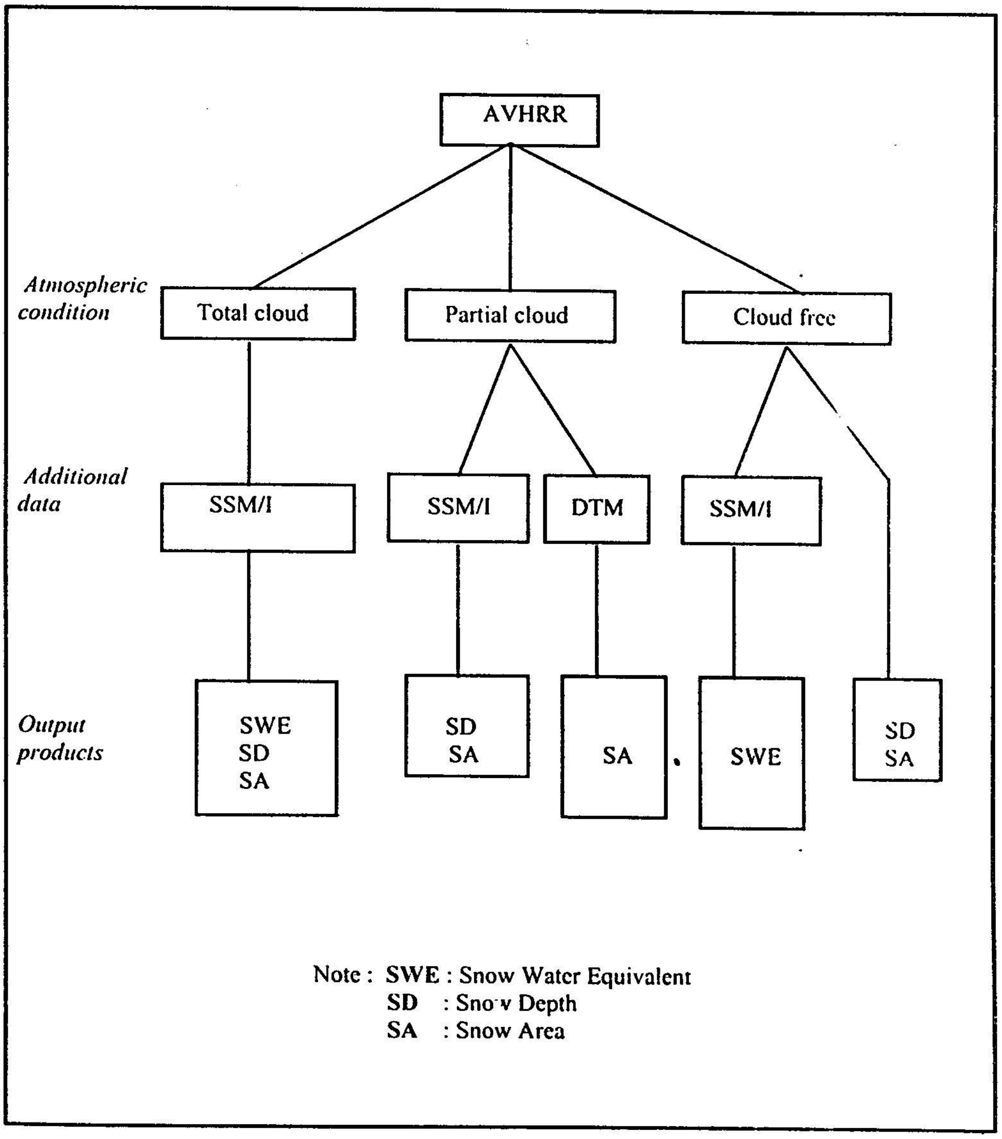

Figure 5. Integration of different data sources under different atmospheric conditions

INSTRUMENTATION

The data logger units , Argos transmitters, pressure transducers as well as the meteorological sensors such as temperature, humidity, solar radiation, wind etc. are installed at various points at the upper catchment of Euphrates river in the month of October 1997.

Meantime, the locally manufactured snow pillows are installed both at the field and at the laboratory for testing. They are pressurised and vacuumed in order to test the transducers for their calibration. They are installed on the sand platforms at the sites ,which were already selected during the previous site visit. The snow depth sensors are mounted on the towers next to the pillow sites in order to keep the continuos records of snow depth and weather temperature as illustrated in Figures for various sites at Eastern Anatolia. Meantime , the snow weight will be measured through the calibrated pressure transducer and these measured values will be recorded in the data logger memory.

The daily records of depth and weight measurements at a present time period are being recorded and being averaged in order to be sent by the Argos transmitter to the main dispatching centre unit in France. The data will then be downloaded through Internet by the research members.

SNOWMELT RUNOFF MODELS

RS and GIS have the potential applications to provide input data for hydrologic models for runoff forecasting . Practical applications in recent years have shown that remotely sensed model variables are an important source of information for models to make them operational . Seasonal snowmelt runoff estimates are extremely important in mountainous areas such as in eastern part of Turkey. The operation of dams located on Euphrates River highly depends on the estimated discharge volumes resulting from snowmelting during the spring months (April-June) .

So the application of runoff models to predict and early forecast of snowmelt is the important part of this study. Areal snow cover map in terms of percentage of snow area as a function of time is called as " Master Depletion Curve " and it is the important input element of the model besides the other parameters to describe temporal and spatial hydrologic and climatologic variables.

The organisational chart of the model application is shown at Figure 6 .

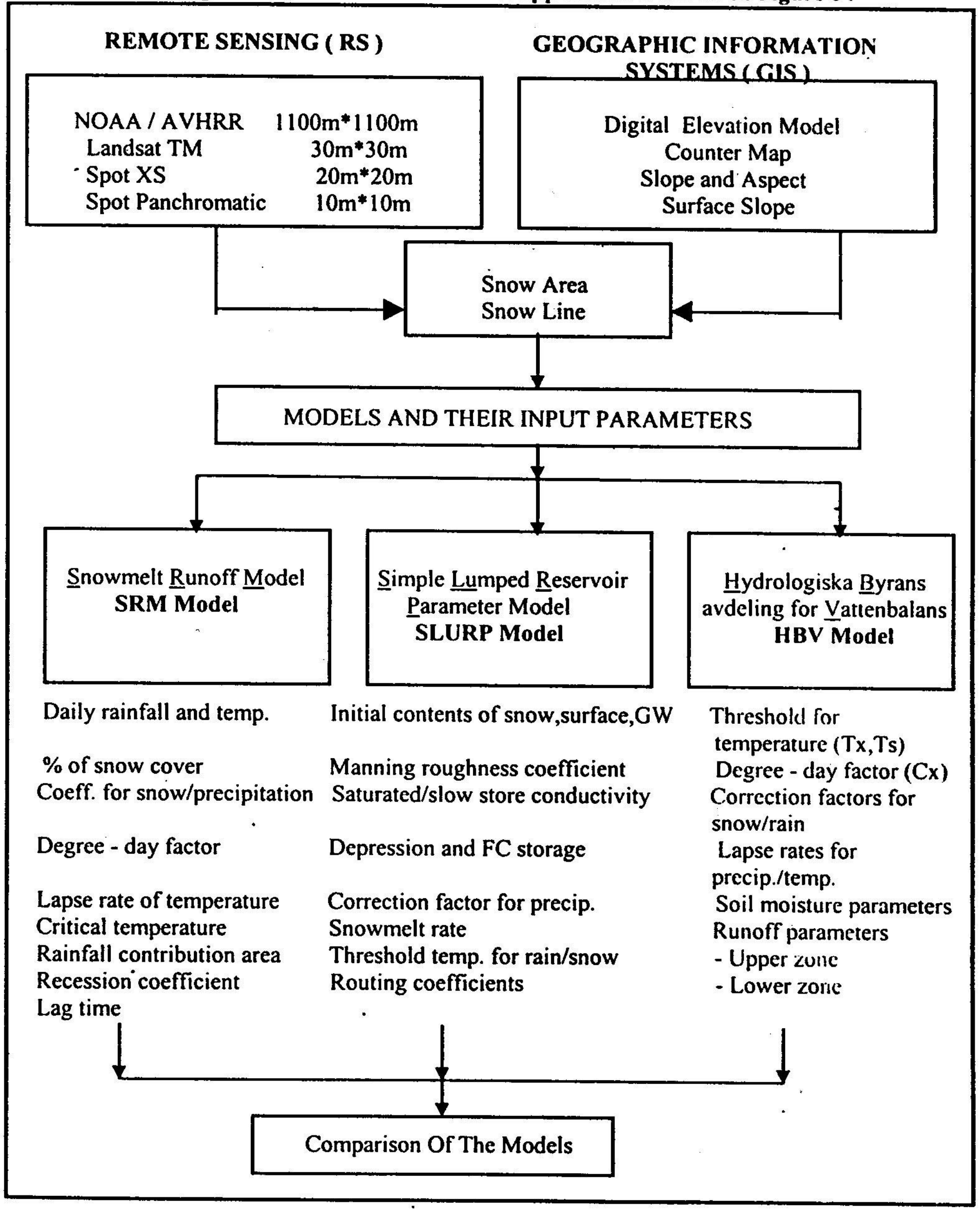

Figure 6. Snowmelt Runoff Models

Considering the possible types of model as :
1 - Snowmelt Runoff Model (SRM) by Rango ,USA
2 - Simple Lumped Reservoir Parameter Model (SLURP) by Kite , CANADA
3 - Norwegian Model (HBV) by SWISS and NORWEGIAN Water Resources Adm.

Sensitive parameters of the models have to be calibrated for their optimum and most effective values so that when they are used for prediction , the estimated values of runoff would be as accurate as the observed streamflow records to produce minimum standard error of estimate which can be mathematically expressed by various forms of error functions.

Each of the model parameters should have certain upper/lower limits, which can be tested either by trial during model calibration stage or by some physical measures or by experiments done in the field or in the laboratory.

DUST SNOW INTERACTIONS

So far we have presented the methodologies used to identify the snow cover at catchment regions and their SRM estimation by various means. All these approaches naturally assumes that there will be a precipitation of snow basing on long term meteorological averages and within certain limitations the snow accumulation can be predicted with reasonable accuracy. The annual extremes often accepted as bad or good luck and if there happens to be a natural phenomenon like volcanic eruptions all efforts immediately devoted to such events for possible causes. Here we present efforts that might be used to understand the factors effecting the wet deposition hence increase the snow accumulation potential during certain season. Its known that the sulfates and nitrates act as a Cloud Condensation Nuclei (CCN), and enhances the formation of clouds (Radke,1992). Together with dust particles that alone act as a Condensation Nuclei (CN) they form clouds that act as a negative feedback mechanism by increasing the albedo (Charlson, et al.,1987). Levin and Ganor.,(1996) has further shown that the air mass reaching to Israel originated from Desert regions contains similar and even larger amounts of sulfates than the air mass approaching from north. The air mass that are enriched with sulfates and desert dust particles results with considerably more wet deposition Levin and Ganor.,(1996). Thus if we can understand the natural processes that links desert origin dust and sulfates then we may even propose a methodology to interfere with it.

The studies carried out by Saydam(1996) have shown that the daytime wet deposition of dust over the marine region enhances the phytoplankton bloom and especially the bloom of coccolithophores. Among coccolithophores the Emiliania huxleyi (E.hux) dominates these blooms and results with extensive production of Dimethyl Sulphonic Propionic Acid (DMSP) that escapes to atmosphere where it finally oxidises to sulfates. The link with E hux and climate is well known process since these algae are major parts of the carbonate cycles and through the release of DMSP and resulting oxidised product sulfate it exerts a negative feedback mechanism on climate. During 1997 snow detection campaign its envisaged to test the intriguing relation amongst the snow accumulation and these algal blooms through dust transport models; satellite detection and wet deposition sampling. The satellite data (AVHRR and Meteosat PDUS) will enable us to detect the air mass patterns as well as cloud dust combinations, the dust transport model will verify the uplift and transport of desert origin dust and the chemical analysis of wet deposition will be used to confirm the presence of sulfates and MSA a precursor of DMSP. If confirmed, this process will enable us to be able to create algal blooms that can be able to emit large amounts of sulfate particles. These sulfate particles will eventually effect the cloud size spectrum and finally leading to effective wet deposition especially over the highlands.

REFERENCES:

Bailey J. O. , Barret , E. C. , Beaumont , M. J. & Herschy , R.W. 1993 : Remote Sensing of Snow by Satellite , NRA , Bristol , R&D Project No. 207

Baumgartner , M. F. 1990 : Snowmelt runoff simulations based on snow cover mapping using digital Landsat MSS and NOAA data , Tech. Report HL-16 , US Department of Agriculture , ARS , Hydrology Lab.

Baumgartner , M. F. & Rango , A. 1995 : A micro-computer based Alpine snow cover analysis system , Photogrametry Engineering and Remote Sensing , 61(12) , 1475-1486

Charlson, R. J., Lovelock, J. E., Andreae, M.O. and Warren, S. G. Oceanic phytoplankton atmospheric sulphur, cloud albedo and climate. ***Nature*** **326, 655-661 (1987)**

Levin. Z and Ganor. E. 1996. The effects of desert particles on cloud and rain formation in the eastern Mediterranean. In "The Impact of desert dust across the Mediterranean, ed. S. Guerzoni and R. Chester, Kluwer, Dordrecht.

Lucas , R. M. & Harrison , A. R. 1989 : A satellite technique for operational snow monitoring in the U.K. , Final Report , RSU , University of Bristol , UK

Martinec , J. , Rango, A. & Roberts , R. 1994 : Snowmelt Runoff Model User's Manual (ed. By M. F. Baumgartner) , Geographica Benensia no. P29 , Department of Geography , University of Bern , Switzerland.

Radke. L. F., 1992: Preliminary Measurements of the size distribution of cloud interstitial aerosols. Precipitation Scavenging, Dry Deposition and Resuspension. Ed. Pruppacher et al. Elsevier sci. Pub. 71-77.

Saydam. A.C. 1996: Can we predict Harmful Algae Blooms. Harmful Algae Newsletter. 15. Dec. 1996 UNESCO/IOC

US Army Corps Of Engineers (1956) Snow Hydrology , US Department of Commerce , Washington DC , USA.