TRAINING COURSE
ON

APPLICATIONS OF REMOTE SENSING AND GIS IN WATER RESOURCES MANAGEMENT

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LECTURE NOTE
ON

FUTURE REMOTE SENSING AND GIS IN WATER RESOURCES

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FUTURE OF REMOTE SENSING AND GIS IN WATER RESOURCES

Introduction

Water is life, in all forms and shapes. This basic yet profound truth eluded many of us in the second half of the 20 th century. Water professionals and scientists around the world are ringing the alarming bells of an impending water crisis. Yet attempts to address some of the issues or to offer partial solutions met with limited success. The ever-growing population and concomitant expansion of agriculture and industry have placed increasing demand on the limited water resources.

'*There is a water crisis today. But the crisis is not having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people and the environment – suffer badly*' (World Water Council, 2002).

To manage the water, we need to know, how much is available and also how much required. Compared to the conventional hydrological science development, geo-spatial technology (remote sensing, GIS, GPS) has made it possible to look at the hydrological responses spatially and also to also to under the water required and also water available spatially, where is required.

Hydrological Cycle & its components

The interdependence and continuous movement of all forms of water on the earth and in the atmosphere is known as hydrologic cycle. The important input for hydrological process is Precipitation.

Precipitation: Recognizing the practical limitations of rain gauges for measuring spatially averaged rainfall over large areas and inaccessible areas, hydrologists have increasingly turned to remote sensing as a possible means for Quantitative Precipitation Information (QPI) especially in areas where there are few surface gauges.

Improved analysis of rainfall can be achieved by improved inverse models, multi-sensor and blended products e.g., CPC rainfall (Passive, SAR, Thermal + Rain Gauge). A multi-sensor, observation technique is shown in figure 1.

Useful data can be derived from satellites used primarily for meteorological purposes, including polar orbiters such as The National Oceanographic and Atmospheric Administration (NOAA) series and the Defense Meteorological Satellite Program (DMSP), and from geostationary satellites such as Global Operational Environmental Satellite (GOES), Geosynchronous Meteorological Satellite (GMS) and Meteosat, and Indian Satellite (INSAT) series. Whereas the visible/ infrared techniques provide only indirect estimates of rain, microwave techniques have great potential for measuring precipitation because the measured microwave radiation is directly related to the rain drops themselves.

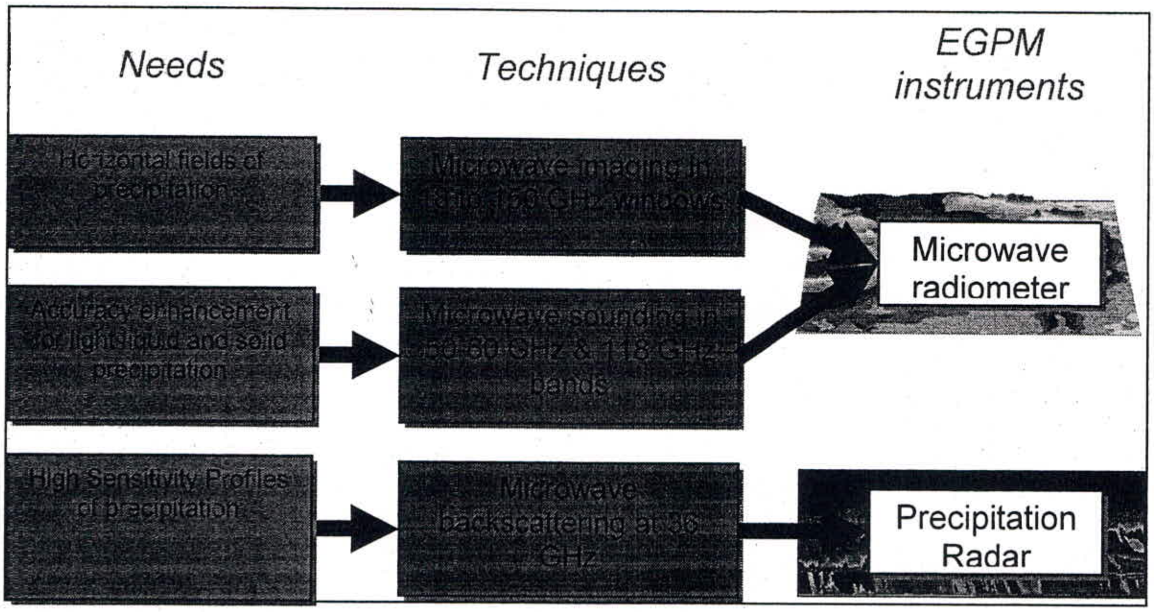


Figure 1: A multi-sensor, observation technique

Spencer et.al., (1988) have shown that the DMSP Special Sensor Microwave / Imager (SSM/I) data can identify rain areas and Adler et.al., (1992) has used a cloud based model with 85 and 37 GHz SSM/I data to estimate rain rates. Ground-based radar, which is a remote sensing technique, has advanced to an operational stage for locating regions of heavy rain, and for estimating rainfall rates also.

Satellite based daily precipitation data product is made using

- Global Telecommunication System (GTS) station data
- GOES Precipitation Index (GPI) infrared cloud top temperature fields derived from Meteosat
- Polar orbiting satellite precipitation estimate data from Special Sensor Micro wave/Imager (SSM/I) on board Defense Meteorological Satellite Program and Advanced Microwave Sounding Unit (AMSU-B) on board NOAA15,16 and 17

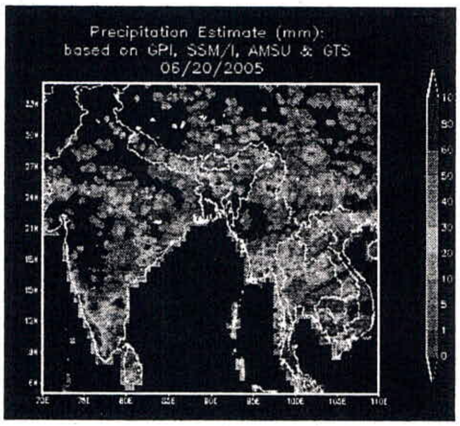


Fig. 2: Precipitation map from NOAA climate prediction centre.

A sample rainfall data is shown as figure 2, which is available from NOAA climate prediction center (**ftp://ftpprd.ncep.noaa.gov**) with a spatial resolution is about 6' (minutes) which is approximately 10 x 10 km.

Snow: Snow is one of the form of precipitation, however, in hydrology it is treated differently because of the lag between when it falls and when it produces runoff, groundwater recharge, and is involved in other hydrologic processes. Remote sensing is a valuable tool for obtaining snow data for predicting snowmelt runoff as well as climate studies, because of its contrast in satellite images and its occurrence in accessible areas. Satellite data in visible/infra-red bands will give only the areal extent of snow cover, however microwave measurements can help in getting snow depth, snow water equivalent etc., which will help in better understanding snow hydrology. As far of now, Passive microwave sensors such as SSM/I or AMSR-E can be used to quantify Snow Water Equivalent (SWE) and also depth also with some accuracy.

$$\textbf{SWE (mm)} = \textbf{A1} + \textbf{A2}\ \frac{\textbf{(TB(19) - TB(37))}}{\textbf{(19 - 37)}}$$

Where

TB(19), TB (37) – Brightness Temperature at 19 and 37 GHz frequencies in SSM/I data A 1, A 2 are regression coefficients.

Fig 3: Snow as seen in AWIFS

$$\textbf{SNOW DEPTH (mm)} = \textbf{A} * \textbf{(TB(19H) - TB(37H))}$$

TB(19H), TB (37H) – Brightness Temperature at 19 and 37 GHz frequencies in Horizontal Polarization in SSM/I data
A – Regression Equation

Soil Moisture: Soil Moisture is the most important component in understanding hydrology of an area. This is difficult to measure in large spatial extents; where as remote sensing has lot of potential in estimating surface soil moisture. The revolution in mapping soil moisture using remote sensing sensors is shown in figure 4. As far now, the soil moisture fields generated are at course resolution in terms of km. However future microwave missions such as RISAT from India and Terra SAR-X with higher spatial resolution of less than 10 m it will be possible to understand spatial spoil moisture variation at watershed level.

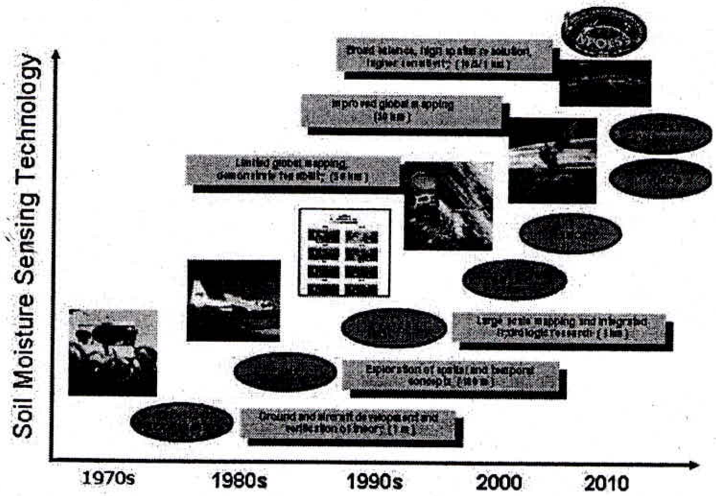


Figure 4: Soil Moisture Remote Sensing Revolution

Recent Developments in Geo-spatial technology

When satellite remote sensing started, way back in early 70s, understanding the catchment's characteristics from where water is generated using these data sets was very helpful. With the improvements in spatial resolution up to less than 1 m, ground sensor technology for data collection and communication equipment, it became possible to combine the data from different sources, improvements in GIS technology.

Remote Sensing, when it was introduced into hydrology in the seventies, held a great deal of promise for hydrology. Inspite of cool acceptance of remote sening, its future impact on hydrology and water resources likely to get great for several reasons.

The ability to provide data, rather than point data.

- The potential to provide measurements of hydrological variable not available through techniques such as soil moisture and snow water content.
- The ability, through satellite sensors, to provide long-term, global-wide data even for remote and generally inaccessible regions of earth.
- The possibility, to acquire RS data for larger areas with high resolution in space and time at one spot and in real time, which may serve as basis for water management decisions in real-time.

If the emerging hydrological sciences are to break away from the traditional engineering hydrology, a number of general specific data needs are going to have to be addresses and solved. Some of them are,

- Hydrological data are needed to measure fluxes and reservoirs in the hydrological cycle and to monitor hydrological change over a variety of temporal and spatial scales.
- Detection of hydrologic change requires a committed international long-term efforts and requires also that the data meet rigorous standards for accuracy
- Synergism between model and data is necessary to design effective data collection efforts to answer scientific questions
- A fundamental block to progress in using most hydrological data is our poor knowledge of how to interpolate between measurement points.

There are potentially many new and exiting observations of hydrological cycle that are going to be available from new satellite mission and their salient features are given here.

HYDROS Hydrosphere States Mission.

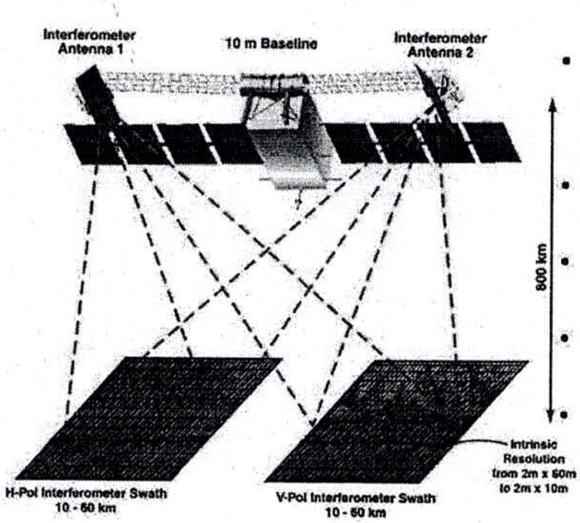
- *A NASA Earth System Science Pathfinder mission;*
- *Surface soil moisture w/ ±4%vol. accuracy and Freeze/Thaw state transitions;*
- *Revisit time: Global 3 days, boreal area 2 days*
- *L-band (1.41GHz) Radiometer sensing 40km brightness temp. with H & V polarization;*
- *L-band (1.26GHz) Radar measuring 1-3km backscatters with hh, vv, hv polarization;*
- *Soil moisture products: 3km radar retrievals, 40km radiometer retrievals, 10km radar and radiometer combined retrievals and 5km 4DDA results.*

SMOS –MISSION for Hydrological applications

- ***SMOS** is a L-band (1.4 GHz) radiometer selected as one of ESA's Earth explorer opportunity missions. This is due for launch in 2007.*
- *Main objectives: Retrieval of surface soil moisture though measurement of surface brightness temperature.*

- *Surface soil moisture retrieval (0- 5 cm): Spatial resolution < 50 km; temporal resolution < 3 days. Standard error < 0.04* m^3/m^3.
- *SMOS is an unprecedented opportunity to measure directly the near surface soil moisture, globally, at an intermediate spatial scale and sufficient revisit period.*

The Water Elevation Recovery Mission



- Ka-band-SAR interferometric system with 2 swaths, 10 km-60km on each side of the nadir track
- Produces heights and co-registered all-weather imagery
- 200 MHz bandwidth (0.75 cm range resolution) for higher resolution imaging
- Uses near-nadir returns for SAR altimetry to fill in nadir swath
- No data compression onboard

Figure 5: Salient features of Water Elevation Recovery Mission

The features of this mission are given below.

- *5-10 cm height accuracy (need height change for storage change, not absolute height)*
  - *River discharge, wetland/lake storage change*
- *Map rivers > 100m width*
  - *Would like to go to smaller rivers*
- *River slope accuracy: 10 mrad (1cm/1km)*
  - *River discharge*
- *Revisit time:*
  - *Ideal: 3 days in the Arctic, 7 days in the tropics*
  - *Acceptable: 7 days in the arctic, 21 days in the tropics*
- *Imager with resolution better than 100 m*
  - *River width, wetland/lake extent*
  - *Should distinguish vegetated/non-vegetated*
- *Global coverage, sampling all major contributors to surface water, is not affected by clouds*
  - *Wetlands, rivers, lakes in tropics, Arctic thaw*

LIDAR Missions

LIDAR remote sensing techniques can be applied to measure a wide variety of atmosphere co parameters important in hydrological sciences, including aerosol distribution, cloud properties and ozone and water vapor concentrations and wind fields.

The incoming solar radiation (isolation) that reaches the earth surface can be measured using remote sensing techniques.

Radiation and latent and sensible fluxes are important processes in land-atmosphere exchanges, which can be quantified using meteorological and remote sensing data (NDVI, albedo, surface temperature etc.).

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