Appendix E
Hydrology

Meteorological Satellite Data

The river and flood forecasting service of the National Weather Service (NWS) produces more than **400,000** forecasts annually for about 2,500 riverside communities from its 13 River Forecast Centers. [1] The NWS, the U.S. Army Corps of Engineers, and the U.S. Geological Survey operate thousands of river gages that transmit data via the geostationary meteorological satellite (GOES) to central sites for near-real-time analysis. Transmission via satellite solves the common problem of interrupted service during floods. All these agencies, as well as local and regional water authorities, are continually expanding their use of satellite transmission of data.

For the past 10 years the metsats have been used for mapping the areal extent of snow in river basins in the Pacific Northwest and California to improve river forecasts on the Columbia River and the rivers draining the Sierra Nevada. Rainfall estimates from convective storms and hurricanes are now routinely done by the National Environmental Satellite Data Information Service (NESDIS) at the National Oceanic and Atmospheric Administration (NOAA). They draw heavily on the satellite measurement of cloud-top temperatures and the rate of growth of cumulonimbus clouds from the half-hourly images taken by the GOES satellite.

Another important unknown in the hydrologic cycle is soil moisture, which controls the amount of precipitation that will form storm runoff. Some thermal infrared experiments indicate that this technique has promise, but no operational soil moisture estimations are currently being made.

Flood mapping from both NOAA polar-orbiting and geostationary satellite imagery and data has been demonstrated under cloud-free conditions on large rivers such as the Mississippi, and on smaller rivers with wide flood plains such as the Red River of the North (North Dakota and Minnesota) and the Kentucky River. The daily coverage of the metsats provides opportunities to map the progress of the flood as it moves across a large basin drainage system. The thermal infrared channels permit nighttime flood mapping.

[1] R A Clark Satellite Applications in River and Flood Forecasting, ' in *Satellite Hydrology* M Deutsch D R. Wiesnet, and A Rango (eds) Proceedings of the 5th Annual W T Pecora Memorial Symposium on Remote Sensing 1979, Sioux Falls, S Dak , 1981, pp 6-8

Several new hydrologic models for basins that have substantial snowmelt contributions have been developed to use the new snow-area data made available by satellites.

The AgRISTARS program of the Department of Agriculture includes a large amount of hydrologic data derived from NOAA satellites. Hydrologic requirements are integrated into almost all sub areas of the program:

- early warning and crop condition assessment,
- commodity production forecasts,
- renewable resources inventory and assessment,
- land-use classification and measurement,
- land-productivity estimates,
- conservation practices assessment, and
- pollution detection and impact evaluation.

Some of the hydrologic information developed from metsat data under the AgRISTARS program involved: flood damage assessment, warning of the onset of drought, soil-moisture modeling, rainfall, solar radiation, vegetation indices, land-use changes, and snowpack characteristics.

NOAA has used satellite data to provide evaporation estimates for Lake Ontario, to detect ice dams on rivers and ice conditions on the Great Lakes, and to determine the best ship routes on the Great Lakes.

NESDIS routinely prepares thermal maps of the Great Lakes. In addition it is able to detect coastal circulation patterns at river mouths, estuaries, lakes, and bays using the thermal infrared channels.

In sparsely settled Canada, the use of metsat data has been widespread. Snow cover mapping, freezeup, and ice breakup on large lakes, flooding, and telemetry of hydrologic data are common applications; because of the vastness and remoteness of much of the Northwest Territory, use of the data is increasing in popularity. The Atmospheric Environment Service, the Canadian Centre for Remote Sensing, and the various Provinces are heavily involved in these hydrologic applications.

Metsat data (channels 1 and 2) are also used to produce vegetation indices. The Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA) has prepared a series of computer-enhanced images of Africa showing by color the vegetation of the country. NOAA/NESDIS now produce vegetation index maps of both the Northern and Southern Hemispheres on a weekly basis (see figures in app. H).

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In Bolivia, GOES data have been used to determine convective storm characteristics in small- or medium-sized basins for the design of dams or other water-resource engineering development. Cloud indexing techniques have improved rainfall estimates in northwest Africa in connection with a desert locust control survey sponsored by the U.N. Food and Agricultural Organization.[2]

Snowpack can be routinely mapped with the l-km resolution Advanced High Resolution Radiometer. Tests in California have shown that these measurements are equivalent in accuracy to traditional aircraft survey techniques.[3] Snow inventory and runoff forecasting in Norway have been done largely through NOAA polar-orbiting satellite imagery, with effective cost savings resulting from improved water-power management.4

Although the U.S. Agency for International Development (AID) has been the lead Federal agency in transferring the technology of remote-sensing to developing countries, it has commonly emphasized Landsat data rather than metsat data. NOAA has run training sessions for a wide variety of scientists and engineers at its U.S. facilities to assist in remote-sensing technology transfer as it pertains to the metsats. Much of this work has been financed by international and AID programs. NASA and the U.S. Geological Survey have also engaged in international on-the-job training for foreign nationals.

Landsat Data

Landsat investigations over the decade have proven the ability of the Landsat system to map floods, snow cover, and ice cover; delineate surface permeability; etc. Used together with meteorological satellite data, they offer a formidable resource survey tool:

- In 1973, some of the most disastrous flooding on the Mississippi River in recent years was mapped with Landsat, vividly delineating the extent of inundation over large parts of a major river basins
- Snow pack extent was mapped in California using Landsat data, resulting in reduced errors in stream flow forecasts. '
- Landsat data have been effectively used in South Dakota to model soil erosion. Landsat's unique contribution was in delineating land cover in the basin. '
- Landsat data have been used to enforce water pollution regulations. In this case they provided the extent of pollution and turbidity levels at a plume in Lake Champlain; these data were used in a court case against a New York papermill.

These examples are only a small sample of the total applications of Landsat data to hydrology. The limitations of the Landsat system in its applications to hydrology are similar to those in agriculture: timely coverage may not be available because of the 16-day repeat cycle. Part of this limitation can be overcome by using meteorological satellite data.

Conjoint Applications of Landsat and NOAA Polar-Orbiting Data

Used together, Landsat and NOAA polar-orbiter data offer a formidable resource survey tool. As in applications to agriculture, the role of Landsat data is to calibrate the more frequently gathered but poorer resolution meteorological satellite data. Some specific examples include:

- Use of Landsat data to calibrate the snow/no snow boundary. Once a reflectance value has been calibrated defining the reflectance of the snow boundary, then the NOAA polar-orbiter data can be used with high accuracy to map the snow boundary at less cost with greater frequency.
- The same rationale outlined for snow mapping works for flooding-i .e., Landsat spectral data—can be used to define a signature for flood-damaged vegetation and actual water areas where vegetation may be seen through the water. Once calibrated with the Landsat data, polar-orbiter spectral data can be applied to map the flood boundaries.
- Land cover and deforestation which may influence a watershed runoff can be mapped using the

[2] E.C. Barrett, "Satellite Rainfall Estimation by Cloud Indexing Methods for Desert Locust Survey and Control," in *Satellite Hydrology*, M. Deutsch, D. R. Wiesnet, and A. Rango (eds.), Proceedings of the 5th Annual W T Pecora Memorial Symposium on Remote Sensing, 1979, Sioux Falls, S.Dak., 1981, pp. 92-100.

[3] D. Wiesnet and D McGinnis, "Hydrological Application of the NOAA-2 Very High Resolution Radiometer," in *Remote Sensing and Water Management, Proceeding No. 17*, American Water Resources Association, June 1973

[4] G. Ostrem, T. Andersen, and H Odegaard, "Operational Use of Satellite Data for Snow Inventory and Runoff Forecast," in *Satellite Hydrology*, M Deutsch, D. R Wiesnet, and A. Rango (eds.), Proceedings of the 5th Annual W. T. Pecora Memorial Symposium on Remote Sensing, 1979, Sioux Falls, S. Dak., 1981, pp. 230-234.

[5] M. Deutsch, F H. Ruggles, P Guss, and E. Yost, "Mapping of the 1973 Mississippi River Floods From the Earth Resources Technology Satellite (ERTS)," in *Remote Sensing and Water Management, Proceeding No 17*, American Water Resources Association, June 1973

[6] A. Rango and P. O'Neill, "Effective Watershed Management Using Remote Sensing Technology," in *Remote Sensing for Resource Management*, Soil Conservation Society of America, Ankeny, Iowa, 1982.

[7] B. J. Ripple and S Miller, "Remote Sensing and Computer Modeling for Water Quality Planning in South Dakota," in *Remote Sensing for Resource Management*, Soil Conservation Society of America, Ankeny, Iowa, 1982

Landsat system, but a calibrated NOAA polar-orbiter data set can be used at less cost.

Clearly the polar-orbiting metsat-Landsat mix offers many advantages that are yet to be applied. Improved delivery of data sets from the NOAA polar-orbiting metsat and Landsat systems would open the way for significant increases in the use of such mixes.