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Combining NWP data, radar data, raingauge data and a hydrological-hydrodynamical model for flood forecasting in Turkey

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Abstract. For Flood Forecasting for four large catchments in Turkey, a combination of NWP data, radar data, raingauge data and a hydrological-hydrodynamical model has been integrated and installed for real-time operation. The project comprises the use of three radars, over 200 raingauges, over 100 water level gauges and numerical weather prediction results in real time.

1 Introduction

In Turkey, the implementation of a flood forecasting and warning system is being conducted by the General Directorate of State Hydraulic Works (DSI) in the framework of the Turkey Emergency Flood and Earthquake Relief (TEFER) project. DSI has selected four pilot catchments for the establishment of the forecasting system: West Black Sea, Susurluk, Gediz and Buyuk Menderes, with catchment areas ranging from 18 000 to 30 000 km^2.

Three new radars have been installed, together with over 200 raingauges and more than 100 water level gauges, all for online monitoring purposes. The data transmission is taking place via satellite and has been operational since 2003.

The flood forecasting system takes real time monitoring data of the regional meteorology and the catchment status, and produces forecasts of the flood state of the catchment. The forecasting system is based on MIKE FLOODWATCH and SCOUT. MIKE FLOODWATCH is a GIS based decision support system for flood management, with MIKE 11 at its core. SCOUT integrates real time numerical weather prediction, radar and raingauge data to produce rainfall forecasts. The system combines the compilation of real time data with rainfall and flood forecasting and presentations of the information and results.

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2 Rainfall forecasting

Rainfall forecasting is based on three different types of data used in real time: numerical weather prediction (NWP), radar data from three radar stations and raingauge data from more than 100 raingauge stations. The NWP data, the radar data and a part of the raingauge data are provided by the Turkish Weather Service DMI, the other data are stemming from DSI stations.

Before being used, all incoming data are quality controlled: raingauge data are checked for extreme values and hidden missing data (Maul-Kötter and Einfalt, 1998). Radar data are checked and corrected for bright band, ground clutter, anaprop, vertical profile and adjusted to raingauges. A part of this work is done on the radar workstation at DMI by SIGMET IRIS software, the other part is performed by SCOUT (Einfalt et al., 2000).

2.1 Radar rainfall forecast

SCOUT is a feature tracking approach to determine echo motion and was first implemented in a suburban county near Paris to control the sewer network (Einfalt et al., 1990). SCOUT is based on the mass centroid method, deriving the displacement vector between consecutive radar scans from the distance of the mass centres of two corresponding radar echoes. The centres are assumed to be representative for individual convective cells or storms. Distinctive features of radar echoes in consecutive scans are identified and recognised, admitting a reasonable degree of change in each of the features. Thus, the history of the echoes is considered. Individual displacement vectors are applied to extrapolate each echo separately. A comparison between the previous forecasts and the actual measurements provides a means for a quality estimation of the current forecast.

As a result, SCOUT provides forecast images and catchment specific time series for the individual catchments for which it has been configured.

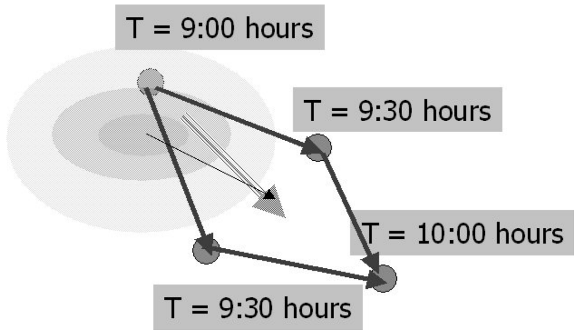

Fig. 1. Determination of the displacement of rainfields based on raingauges.

2.2 Rainfall forecasting with the help of raingauge measurements

In a real time environment, radar data are not always available. Therefore measurements from a raingauge network can work as a fallback strategy for getting rainfall information. For the support of the forecast module in SCOUT, an approach has been developed, linking raingauge data from the raingauge network, mesoscale numerical modelling, and extreme value statistics for a rainfall forecast over 72 h lead time.

The raingauge based forecast uses the locally measured information through the first hour of lead time by applying a spatio-temporal rainfall analysis. This analysis procedure takes advantage of the fact that rainfields arrive at different instants in time at the different raingauge stations. Thus, arrival time at the stations implies a direction and a speed of movement for the rainfield (Fig. 1). A least squares algorithm computes the most suitable movement.

The different modules combine the maximum information available for the catchment (Fig. 2). The radar provides a spatial view of the rainfall over the catchment and is used for nowcasting purposes up to one hour, the raingauge network describes the actual state in the catchment and can be used for nowcasting purposes up to one hour, if no radar forecast is available.

After approximately one hour, the reliability of radar or raingauge based forecasts tends to be more uncertain, and the numerical model results, provided by the ECMWF model used by DMI, are included for the following time period. In this way, rainfall measurements during the current NWP forecast period can be taken into account for the 72-hour forecast.

3 Flood Forecasting

For flood forecasting, FLOODWATCH has for the first time been operationally coupled simultaneously to input from raingauge data, from SCOUT radar data measurements and forecasts of three different radars, and from numerical weather prediction results.

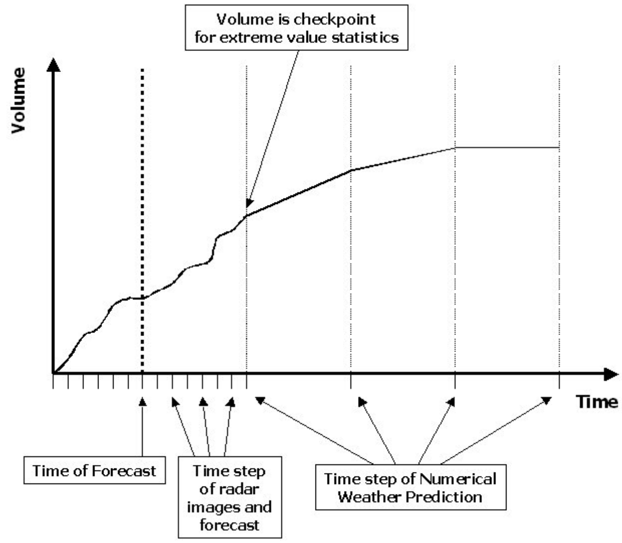

Fig. 2. Integration of rainfall time series with NWP data.

The flood forecasting system is set up within MIKE FLOOD WATCH and comprises the following "push button" operations (Fig. 3):

- Real time data assimilation and preparation
- Hydrologic-Hydrodynamic module, describing the rainfall-runoff process, and the propagation of flood waves through the river system
- Flood Forecasting module, incorporating an updating procedure to ensure maximum and most effective use is made of the available real time information on the catchment
- Flood Mapping module, providing real time flood maps of selected flood prone areas, showing the area and depth of the actual and historical flooding
- Presentation of forecasts in a variety of formats (tables, plots, maps), and uploading to the Internet

3.1 Hydrologic Module

The hydrologic module of the forecasting system takes forecast rainfall as its primary input, and simulates the land phase of the hydrologic cycle to forecast the runoff to the main rivers. The module is based on the NAM (rainfall-runoff) component of the MIKE 11 modelling system. NAM operates by continuously accounting the moisture content in four interrelated storages representing the physical elements of the catchment:

- Snow layer (distributed by altitude)
- Surface zone (vegetation, small channels and lakes)
- Root zone (the depth from which plants draw water)

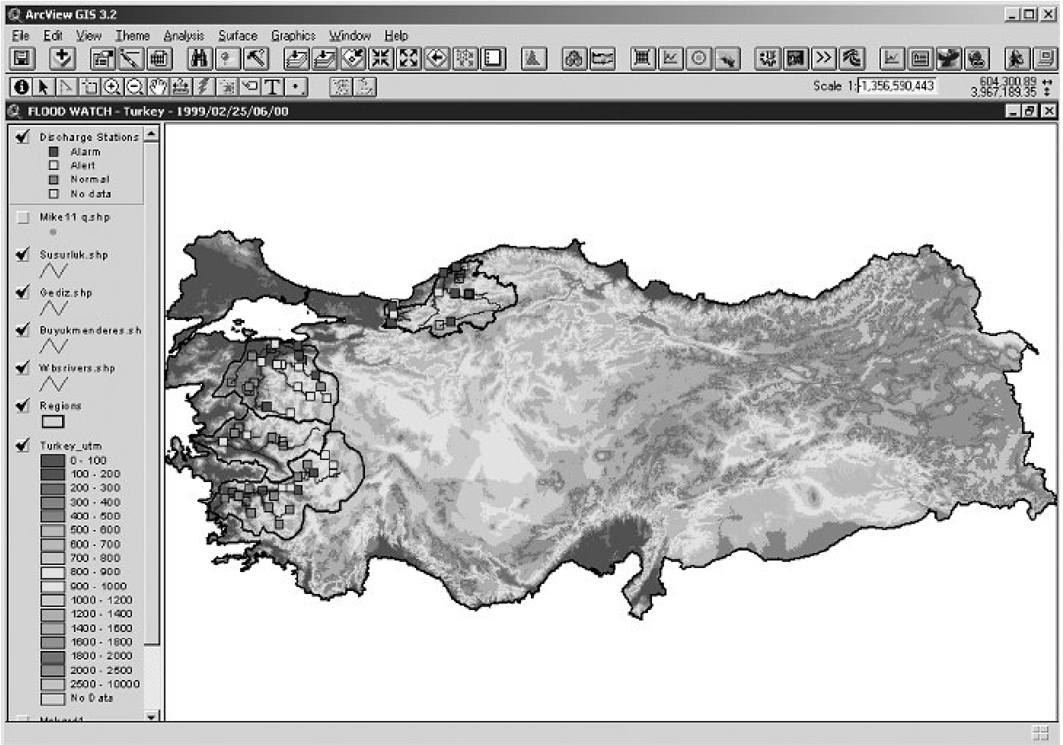

Fig. 3. FLOOD WATCH Application for Turkey.

– Ground water

The forecast rainfall over each subcatchment (average area around 1000 km^2) is received in real time from SCOUT. With real time evaporation and temperature (for snowmelt), the module forecasts the total catchment runoff and effective precipitation to the hydrodynamic module. The module has been calibrated against available historical discharges from 1995 to 2000.

3.2 Hydrodynamic Module

The Hydrodynamic Module has been set up using MIKE 11, with an automatic linkage to the NAM rainfall-runoff module to receive the runoff from the dry areas of the sub-catchments and the direct effective precipitation on lakes and flooded areas. The module uses an implicit finite difference scheme for the computation of steady and unsteady flows in open channels. The module describes critical and subcritical flows through a numerical scheme which adapts to local temporally and spatially varying flow conditions. The high order wave formulation applied is particularly suited to flood wave propagation through steep rivers in the upstream catchment. Advanced computational modules are applied to the description of flows through fixed and movable hydraulic structures.

3.3 Other Modules

Other modules on the hydrological side of the forecast system are the flood forecast module, the flood mapping module and the flood warning module. All of them have been set up to run in close communication for the four catchments that are supervised. Warning informations are issued via web-based services as well as inside the Flood Control Centre in Ankara.

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