Rainfall Runoff Modeling
Using Doppler Weather Radar
For Adyar Watershed, Chennai

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AGENDA

- Need For The Research
- Objectives
- Introduction
- DWR Products And Z-R Relationship
- Advantages And Disadvantages
- Methodology
- Study Area Selection
- HEC-HMS Model
- Results And Discussion
- Conclusion & Future Research Recommendations
Was it raining around Chennai during December 2002–March 2003?

- During late December 2002 – March 2003, reflectivity as high as 28-38 dBZ was observed around Chennai.

- It would have been as if 20-60cm rainfall received over an area of about 600-1600 sq. km around Chennai during Jan – Mar 2003.

But there was no report of rainfall from Met. office/public over these areas.
OBJECTIVES

- Simulate the rainfall-runoff process with HEC-HMS using conventional rain gauge data.

- Simulate the rainfall-runoff process with HEC-HMS using radar derived rainfall data.

- Compare the capability of the two different measurement systems in order to give correct input to derive rainfall-runoff model.

Data Collection:

- State Ground and Surface Water Resources Data Centre (PWD), and India Meteorological Department (IMD) for rain gauge data.

- Cyclone Deduction Radar Centre (CDR), Port Trust, Chennai for radar derived rainfall data.
INTRODUCTION

- Precipitation is a significant input for hydrological models; so, it needs to be quantified precisely.

- At present, the measurement of rainfall in a watershed is based solely on rain gauges network - assumption that it is uniform over the area - under or over estimation of runoff.

- There are numerous papers showing the improvements in flood estimation and flood forecasting using radar rainfall as the input data to the hydrological models.

- Limited studies are carried out in India to utilize the weather radar products for hydrological purposes.

- Utilization of DWR products for hydrological purposes similar to rainfall-runoff modeling, flood forecasting, flood zone mapping, and R&D activities.
DWR Products and Z-R Relationship

CDR provides continuous data on various meteorological parameters;

- Rainfall Data (SRI and PAC)
- Wind speed and Wind direction
- Temperature
- Humidity
- Air pressure
- Visibility

\[ Z = A R^b \]

- \( Z \) - Measured Radar Reflectivity in mm\(^6\)/m\(^3\)
- \( R \) - Rain rate at ground level in mm/hr
- \( A, b \) are constant and it varies from place to place, time to time and for different types of rainfall events.

Radar operating in the CDR, Chennai Port Trust has the following Z-R Relationship,

\[ Z = 267 R^{1.345} \]

Error due to Ground clutter, Attenuation, Bright band and Vertical profile need to be corrected.
ADVANTAGES AND DISADVANTAGES

- The weather radar, which is a widely used basis for rainfall estimation at fine spatial and temporal resolutions, can better capture the spatial variation of rainfall fields than rain-gage rainfall data, in areas where rain-gages are distributed sparsely.
- Approaching storms can sometimes be observed before they reach the catchments of interest.
- It can be used as a forecasting tool for flash flooding and severe thunderstorm.
- It can supplement the existing rain-gages.
- It determines the intensity of precipitation.
- It helps to plan watershed management, based on the rain estimation over the catchments.

- The weather radar does not measure rainfall directly; algorithms are used to estimate the rainfall from radar observations. The radar data requires vigorous quality control before being converted into precipitation products that can be used as input to hydrologic models.
METHODOLOGY

Cartosat 30 m DEM from NRSC

Rainfall Data Collection (radar & gauge)

Watershed delineation - using HEC-GeoHMS (GIS pre processor)

Reformat, Geo-reference the Radar Data using VB Script/ArcGIS

Parameters calculation using Soil and Landuse maps

Loading Precipitation grids into DSS

Basin Model, Meteorological Model, Control Specification creation in HEC-HMS

Simulation of Rainfall-Runoff Process

Compare Radar & Rain gauge runoff

Analyze the discrepancies and provide suggestions
METHODOLOGY – Radar Data Processing

- Radar Rainfall Data Collection from CDR, Chennai
- Reformat the Radar Data to Standard ASCII format using VB Script
- Calibrate the Radar Data using PERL Tool
- Geo-reference the Radar Data using ArcGIS
- Create Single Grids (DSS files) using asc2dssGrid Tool and VB Script (Batch Processing)
- Creating Grid Set from Single Grids using HEC-GridUtil 2.0
Original Radar Data
Text Files to ASCII Data Conversion

Text Files Folder Path: My PAC\01 - Original Radar Data\01 - Raw Text Data
Asc File Folder Path: Hourly PAC\01 - Original Radar Data\02 - ASCII Data

Text To Asc

Microsoft Excel

Text File To ASC Conversion is Completed!!!
ASCII Radar Data

**ncols** refers to the number of columns in the grid

**nrows** refers to the number of rows in the grid

**xllcorner** refers to the western edge of the grid

**yllcorner** refers to the southern edge of the grid

**cellsize** refers to the resolution of the grid

**nodata_value** refers to the value that represents missing data
Radar Data – Projection

Radar Data Projection - ArcGIS

Radar Data Projection – HEC-GridUtil 2.0
ASCII Data to DSS(Single Grids) Conversion

Using asc2dssGrid Utility and VBScript (for Batch Processing)
Grid Set(DSS) creation in HEC-GridUtil 2.0
HEC-DSSVue Utility for DSS File Editing

Time period is from 7 November 2010, 03:00 to 7 November 2010, 04:00
Units: mm; Type: 1

Axis | Lower Left | Number
---- | ---------- | -----
K    | 645        | 400   
Y    | 2690       | 400   

Cell Size: 500.0

Maximum Value: 89.30
Minimum Value: 0.00
Mean Value: 6.21
Radar Rainfall Information Extraction

C:\Users\acer\Desktop\session e4\Daily PAC - without Calibration
## Radar – Rain Gauge Data comparison

<table>
<thead>
<tr>
<th>Rain Gauge Stations</th>
<th>Nungambakkam</th>
<th>Tharamani</th>
<th>Meenambakkam</th>
<th>Tambaram</th>
<th>Chengalpattu</th>
<th>Korattur</th>
<th>Sriperum</th>
<th>Pudur</th>
<th>Chengalpattu</th>
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<td>0.00</td>
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<td>0.00</td>
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<td>05-Nov-10</td>
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<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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<td>06-Nov-10</td>
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<td>10.00</td>
<td>2.60</td>
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<td>2.20</td>
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<td>20.90</td>
<td>17.00</td>
<td>19.70</td>
<td>14.30</td>
<td>17.40</td>
<td>11.90</td>
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<td>08-Nov-10</td>
<td>9.60</td>
<td>13.50</td>
<td>10.00</td>
<td>36.90</td>
<td>31.80</td>
<td>6.80</td>
<td>18.90</td>
<td>37.59</td>
<td>37.59</td>
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<td><strong>Sum</strong></td>
<td><strong>31.80</strong></td>
<td><strong>36.60</strong></td>
<td><strong>38.00</strong></td>
<td><strong>60.20</strong></td>
<td><strong>62.70</strong></td>
<td><strong>25.20</strong></td>
<td><strong>31.80</strong></td>
<td><strong>71.39</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rain gauge data (mm)</th>
<th>04-Nov-10</th>
<th>05-Nov-10</th>
<th>06-Nov-10</th>
<th>07-Nov-10</th>
<th>08-Nov-10</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-Nov-10</td>
<td>1.80</td>
<td>3.80</td>
<td>3.80</td>
<td>22.80</td>
<td>47.80</td>
<td>80.00</td>
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<tr>
<td>05-Nov-10</td>
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<td>0.00</td>
<td>0.00</td>
<td>5.00</td>
<td>0.00</td>
<td>5.00</td>
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<tr>
<td>06-Nov-10</td>
<td>4.80</td>
<td>0.00</td>
<td>5.00</td>
<td>21.40</td>
<td>44.80</td>
<td>64.60</td>
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<tr>
<td>07-Nov-10</td>
<td>1.00</td>
<td>0.00</td>
<td>8.00</td>
<td>11.20</td>
<td>49.00</td>
<td>69.20</td>
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<tr>
<td>08-Nov-10</td>
<td>5.00</td>
<td>5.00</td>
<td>12.00</td>
<td>5.00</td>
<td>37.00</td>
<td>69.00</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>13.00</strong></td>
<td><strong>6.00</strong></td>
<td><strong>12.00</strong></td>
<td><strong>17.20</strong></td>
<td><strong>53.00</strong></td>
<td><strong>83.00</strong></td>
</tr>
</tbody>
</table>
Calibration of Radar Data

Radar rainfall calibration factor for the study area is identified as 1.786

Radar Vs Rain gauge Data

\[ y = 1.786x \]
\[ R^2 = 0.441 \]

Radar Rainfall Calibration Model (Original Values)

Radar rainfall calibration factor for the study area is identified as 1.786
Radar Rainfall Calibration – PERL Batch Program
ASCII Radar Data – Before Calibration
Radar Rainfall Calibration Model (Adjusted Values)

Calibrated Radar Vs Rain gauge Data

\[ y = 1.000x \]
\[ R^2 = 0.441 \]
STUDY AREA SELECTION

Area of the watershed: 632 km²
Average Annual Rainfall: 1200 mm
Average Monthly Minimum Temperature: 19º C
Average Monthly Maximum Temperature: 42º C
Basin Model – Grids with HMS nodes and Links
Adyar Landuse Map
Basin Model – Parameters
HEC-HMS Model
OUTLET RUNOFF (m³/sec)

RUNOFF - CALIBRATED RADAR INPUT
RUNOFF - RAIN GAUGE INPUT
RUNOFF - ORIGINAL RADAR INPUT

DATE/TIME

04-NOV-10 05-NOV-10 06-NOV-10 07-NOV-10 08-NOV-10 09-NOV-10

08:30 12:30 16:30 20:30 00:30 04:30

04-NOV-10 05-NOV-10 06-NOV-10 07-NOV-10 08-NOV-10 09-NOV-10

08:30 12:30 16:30 20:30 00:30 04:30
RESULTS AND DISCUSSION

<table>
<thead>
<tr>
<th>Watersheds</th>
<th>Sub1 - Nemam (Ungauged)</th>
<th>Sub2 - Adyar (Gauged)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calibrated Radar Data</td>
<td>Rain Gauge Data</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Peak Outflow (m³/sec)</td>
<td>90.5</td>
<td>92.3</td>
</tr>
<tr>
<td>Date of Peak Outflow</td>
<td>07-Nov-10</td>
<td>07-Nov-10</td>
</tr>
<tr>
<td>Total Outflow (1000m³)</td>
<td>3168.6</td>
<td>4574.8</td>
</tr>
<tr>
<td>Discrepancy</td>
<td>30.74%</td>
<td></td>
</tr>
</tbody>
</table>

- Original Radar Rainfall data is quite low when compared to the rain gauge rainfall data, so it needs to be calibrated.

- Simulated values obtained from the model using Calibrated radar and rain gauge inputs are compared and difference in peak outflow is 12 % for Gauged watershed whereas it is 30 % for ungauged watersheds.

- The model prediction using radar data and field discharge are in fair agreement.
Severe Cyclonic Storm Jal near Chennai, Tamil Nadu,

- **Formed**: October 31, 2010
- **Dissipated**: November 8, 2010 (Monday)
- **Highest winds**:
  - 3-minute sustained: 110 km/h (70 mph)
  - 1-minute sustained: 100 km/h (65 mph)
- **Fatalities**: at least 118 dead, 12 missing
- **Damage**: $1.729 billion (2010 USD)
- **Areas affected**: Malaysia, Malay Peninsula, Sri Lanka, India

Part of the 2010 Pacific typhoon season
&
2010 North Indian Ocean cyclone season

Severe Cyclonic Storm Jal near Chennai, Tamil Nadu, India, at peak intensity on November 7, 2010 (Sunday)

Power outages occurred at many places in Tamil Nadu and Andhra Pradesh throughout Sunday.

One person was killed in Chennai, Tamil Nadu when a tree toppled.

On November 9, the Andhra Pradesh chief minister Konijeti Rosaihsaid that about 54 have died in India due to the storm.

Media news

'JAL' weakens into cyclonic storm PTI Nov 7, 2010, 06.32pm IST

CHENNAI: Severe cyclonic storm 'JAL' has weakened into a cyclonic storm and lay centred over southwest Bay of Bengal, about 250 km east-southeast of Chennai, today even as two persons died in rain-related incidents in Tamil Nadu.

Jal, which means water in Hindi, will bring thunderstorms.
CONCLUSION

➢ Research investigates the feasibility of using DWR rainfall data for hydrological purpose in Chennai watersheds.

➢ Radar outflow pattern matches the observed outflow.

➢ The research concludes that DWR products available at CDR, Chennai can be used for hydrological purposes such as runoff estimation, flood forecasting, flood zone mapping, and Research and Development activities because of the benefits of their spatial and temporal information content.
FUTURE RESEARCH RECOMMENDATIONS

- DWR station is applying unique Z-R relationship, it may not be appropriate.

- Study area has inadequate automatic rain gauges, both recording as well as non-recording rain gauges are considered.

- Research will be extended to simulate rainfall-runoff for the entire watersheds in Chennai basin to assist the policy and decision makers for better planning and development activities, especially in remote areas where rain gauges are sparse.
Thank you