The Past, Present, and Future of Flash Flood Prediction
NWS Flash Flood Guidance System

- **Flash Flood Guidance (FFG):** average rainfall over a specified area and time duration required to initiate flooding on small streams
- FFG (mm) computed for accumulation periods of 1-, 3-, 6-hr (12, 24 also used)
- If rainfall exceeds FFG, then a forecaster will consider issuing a flash flood warning
How is FFG derived?

- Lumped SAC-SMA model run under different rainfall scenarios to produce rainfall-runoff curves
- Curves subject to change due to initial soil moisture states, evapotranspiration
- Thresh runoff values (pre-computed) looked up on curves to get FFG
Evaluation of the Operational Tools used for Flash Flood Forecasting in the US

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NWS Advanced Hydrologic Prediction Service

NSF Graduate Research Fellowship
FFG Production

- **LFFG – Lumped FFG**
  - Lumped-parameter basins (~300 – 3,000 km²); SAC-SMA model
- **GFFG – Gridded FFG**
  - high-res product based on NRCS Curve Number method
- **DFFG – Distributed FFG**
  - Continuous-API (Antecedent Precipitation Index)
- **FFPI – Flash Flood Potential Index**
  - Quasi-static; geographical characteristics (slope, land cover, wildfire, soil type, …)
Study Period
1 Oct 2006 – 31 Aug 2010

Changes in FFG generation method occurred in late 2007 or early 2008
Map of what type of FFG runs at various RFCs

USGS Gauge Locations
1 October 2006 - 31 August 2010
at least 1 "action stage" exceedance
contributing drainage area < 260 km^2
HITS

Black Arrows

MISSES

– Red Arrows

No FALSE ALARMS – all contiguous areas of ratio > 1.0 have at least one observation

Stage IV-to-FFG ratio, 19 Aug 2007 06z

3.63

> 0

Flash flood observations
NWS Norman
04z - 12z, 19 Aug 2007
Results – NWS Storm Data Analysis
Results – USGS Stage Height Analysis
Conclusions/Recommendations

- All methods of FFG in all regions have low CSI (high false alarms; low probability of detection)
  - CSI = 0.19 over Middle Atlantic RFC using 1-hr DFFG & 1.25 QPE-to-FFG ratio
  - This value should be considered as the benchmark skill for future developments
- Both evaluations indicate the worst performance was in CNRFC, CBRFC, NWRFC, and NERFC
- NWS Storm Data has large sample sizes, so we use it for intercomparison
  - DFFG is best method
  - LFFG and GFFG have similar skill but GFFG has better resolution
  - FFPI has lowest skill and should be used sparingly
- National system w/consistent skill desirable; but include ability to include local modifications

http://www.nssl.noaa.gov/projects/flash
Threshold frequency method for flash flood prediction

1. Take longest available gridded rainfall record
2. Simulate flow with hydrologic model for period of rainfall recording annual maximum flows @ each grid cell
3. Compute Log-Pearson III distribution from annual maximum sim flows (gives mean, standard deviation and skew parameters)
4. From this distribution estimate we can estimate return period for any discharge value at every grid point

Inherent bias correction for inputs+model

Reed et al. (2007)
Ensemble Framework For Flash Flood Forecasting (EF5) supports 2 distributed models

- **CREST**
  - Concepts from Xinanjiang model
  - Runs operationally over globe at OU and NASA
  - Has a priori parameters
  - 1-km/5-min resolution

- **HL-RDHM**
  - Concepts from SAC-SMA model
  - Runs operationally in US NWS
  - Has a priori parameters
  - 4-km/1-hr resolution

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Figure adapted from UC-Irvine

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Wang et al. (2011) *Hydrol. Sci. J.*

CREST – a priori parameters

Roughness coefficient controls quickflow routing speed

Saturated hydraulic conductivity controls slowflow routing speed

\[ \sum R_{O,in} \]

\[ \sum R_{I,in} \]

1/(Manning N)

Ksat

% Impervious Area

(a)
2-yr return period simulated flows from NEXRAD archive (2002-2010)
FLASH: Flooded Locations and Simulated Hydrographs

A demonstration system for real-time flash flood prediction
The 1D (traditional) way of doing hydrology
National Mosaic and Multi-Sensor QPE (NMQ) Flooded Locations And Simulated Hydrographs (FLASH) - A CONUS-wide flash-flood forecasting demonstration system

NMQ/Q2 Rainfall Observations - 1km²/5 min
Stormscale Rainfall Forecasts

CREST Stormscale Distributed Hydrologic Model - 1km²/5 min

Probabilistic Forecast Products on the Flash Flood Impacts

Type of flash flood impact according to SHAVE database

Simulated surface water flows and return period

150
200
250 mm

10-11 June 2010, Albert Pike Rec Area, Arkansas

20 fatalities

Probability of life-threatening flash flood
Morning of June 14th, 2010
12” of rain in < 6 hours!
Lots of flooding & property damage, thankfully no loss of life

Photos courtesy of OKC Dept. Public Works
Comparison of Q2 radar-only 24-hr rainfall to Mesonet gauges

Gauges vs QPE
24hr QPE: Q2 [Radar Only]

Valid Period: 06/13/2010 20:00 - 06/14/2010 20:00 UTC
Gauge Groups: OCS

Scatter Plot:

Gauges In Region: 116
Total With QPE: 116

<table>
<thead>
<tr>
<th></th>
<th>Gauge</th>
<th>QPE [mm]</th>
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<tbody>
<tr>
<td>Max</td>
<td>259.59</td>
<td>252.30</td>
</tr>
<tr>
<td>Avg</td>
<td>30.12</td>
<td>36.51</td>
</tr>
<tr>
<td>Min</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Stats:

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<tr>
<th></th>
<th>[Y/Y]</th>
<th>[Y/Y+N+N/Y]</th>
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<tbody>
<tr>
<td>Total Bias</td>
<td>1.21</td>
<td>1.21</td>
</tr>
<tr>
<td>Corr Coeff</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>RMSE [mm]</td>
<td>14.80</td>
<td>14.80</td>
</tr>
</tbody>
</table>

Region:

106.00W 40.00N 90.31W 32.00N

Mask: none
Verif Mode: 1pt
Accum>=0%
Evaluation of Flash Flood Simulations

SHAVE Reports
- No Flooding
- Flooding
- Severe Flooding

Severe Hazards Analysis and Verification Experiment
Ortega et al., BAMS (2009)
Rainfall from NMQ/Q2 Radar-Only Product (5 min/1 km)

Streamflow from CREST Distributed Hydrologic Model (5 min/1 km)

Frequency estimates based on 10-yr StageIV reanalysis
Hurricane Sandy Flooding

Observed Flood Stage
- Green: No Flooding
- Yellow: Action
- Orange: Minor
- Red: Moderate
- Purple: Major

Simulated Return Period (y)

Legend:
- 200
- 0
Hurricane Irene

- Q2 Radar Only QPE
- Stage IV reanalysis from 2002-2011 to produce estimated simulation return periods
Distributed Flood Severity Index
Ensemble Framework For Flash Flood Forecasting (EF5)

Precip Forcing
- Q2 rainfall rate
- Q2 precip type
- TMPA-RT
  - NWP forecasts

Evapotranspiration
- FEWS NET PET
- HRRR temp, etc
- Land surface model

Snowmelt
- SNOW-17
- HRRR temp

State Estimation (EnKF)
- USGS streamflow
- AMSR-E soil moisture

Surface Runoff
- SAC (HL-RDHM like)
- VIC (CREST like)
- HyMOD

Routing
- Kinematic wave
- Linear reservoir

Forecast
- Threshold frequency
- Probability of flood
- Probability of damage

Groundwater
- MODFLOW

Param Estimation (DREAM)
- USGS streamflow
- AMSR-E soil moisture
Probabilistic Flash Flood Forecasting using Ensemble Stormscale Precipitation Forecasts

Jill Hardy
Gina Hodges

NSF Graduate Research Fellowship
Maximum Return Periods – OKC Flash Flood

Q2 (observed)

Best member

Ensemble mean

Probability matched mean

Promising performance from a 12-hr forecast!
The use of SHAVE and NWS flash flood reports for impact characterization and prediction

Martin Calianno

Laboratoire d'étude des Transferts en Hydrologie et Environnement, Grenoble, France
Are simulations of flash flood severity related to economic impact?
How does FLASH differ from DHM-TF package?

- **Resolution**: FLASH runs on back-end of NMQ/Q2 rainfall generation and provides forecasts at the flash flood scale (1 km/5 min presently, with upgrade to 250 m in March vs. 4 km/1 hr)
- Probabilistic instead of deterministic
- Will incorporate GIS exposure factors to yield impact-specific products
- Framework readily accommodates forcing from contemporary QPFs (e.g., stormscale ensembles)
- FLASH is a centerpiece for R&D
Current Status

- Flash-flood forecasts running at 1 km²/5 min resolution over CONUS
- Based on single member from CREST model
- Scheduled for testbed implementation in July 2013 at NCEP Hydrometeorological Prediction Center


