Radar-Based Tools for Flash Flood Forecasting in the National Weather Service (USA)

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NEXRAD-based Multi-Radar Multi-Sensor (MRMS) System

159 radars
S band
Polarized

Mosaic of reflectivity from NEXRAD and Environment Canada radars
MRMS captures rainfall at flash flood scale

- NEXRAD Radar-only
- 2-min frequency
- 1-km$^2$ spatial resolution
- Covers continental US (for the most part)
Continental-scale Flash Flood Modeling

NEXRAD-based rainfall estimates from the Multi-Radar Multi-Sensor system

Hydrologic forecasts of flash floods downstream from the causative rainfall

Raders: Technologies, Méthodologies et Applications 19-20 Nov 2019
New system in the National Weather Service for predicting flash floods

- Project funded under Public Law 113–2: Disaster Relief Appropriations Act, 2013

- The Flooded Locations and Simulated Hydrographs Project (FLASH) was launched for monitoring and predicting flash floods: Gourley et al. (2017) DOI: 10.1175/BAMS-D-15-00247.1

- Provides forecasts across the US with updates every 2-10 min using 10.8 million grid points

- Transitioned to the National Weather Service in November 2016; rapidly evolved tools for flash flood prediction
Summary of FLASH products

- **Rainfall Average Recurrence Intervals (ARI):** Comparison of MRMS QPE to static thresholds

- **QPE-to-Flash Flood Guidance Ratios:** Comparison of MRMS QPE to dynamic thresholds

- **Distributed hydrologic model forecasts:** 0-12 hr forecasts of discharge, unit discharge, soil saturation
Modeling: What is Flooded Locations and Simulated Hydrographs project (FLASH)?

- High resolution rainfall (1 km, 2 min) from 158 NEXRAD radars
- 0-12 hour forecast of surface water flows (1 km, 10 min)
Utilizes the Ensemble Framework for Flash Flood Forecasting (EF5) to develop Coupled Routing and Excess Storage (CREST) model (Wang et al. 2011)

Mass balance and kinematic wave routing

Model Parameters: Impervious area, available water capacity, soil texture & depth, saturated hydraulic conductivity, etc.
May 31, 2013 OKC Flash Flood: Rainfall

- Composite reflectivity animation
- Supercell storm with quasi-stationary core over Oklahoma City metro area

250 mm
During the storms, 23 people lost their lives (12 from flooding in OKC). This is the deadliest flood in OKC history & the worst in the state since 1984.

Reports from Twitter, Facebook, KFOR-TV, KOCO-TV, News9, and The Oklahoman; Photos from The Oklahoman
Both products indicate greatest threat is to the northwest of the region that was most heavily impacted.

All blue dots correspond to known flooding reports collected from City of Oklahoma City, media, social media (rescues, water in homes, street closures, fatalities).
FLASH Forecast Streamflow

20130531_2200

Streamflow (cms)

1e-02  1e-01  1  10  100  1000  10000
Streamflow forecasts from EF5 distributed hydrologic modeling framework correctly highlight the metropolitan area due to:

1. Routing

2. Modeling of impervious surfaces
History of successful research to NWS operations

- First demo of multisensor QPE using NEXRAD mosaic

- Project launched following funding from Public Law 113-6, the FY2013 Disaster Assistance Supplemental

- HMT-Hydro experiments

CRAFT
- Transfer of real-time radar data on internet

07 98

Postdoc at Météo France

04 0506

NMQ/Q2
- QPE produced in real-time across

MRMS/Q3
- QPE and severe weather products transitioned for operational use in the NWS

FLASH
- Flash flooding software transitioned for operational use in the NWS

FLASH
Future of forcings from a flash flood forecasting perspective

- Use of QPFs from NSSL’s Experimental Warn-on-forecast System using Ensembles (NEWS-e)
  - Potential to increase lead time
  - Accommodates change in paradigm to probabilistic forcings and products

- Use or Probabilistic QPEs (Kirstetter et al. 2015, WRR)
  - Acknowledges uncertainty in radar-based QPE
  - Inherent bias correction
  - Provides moments of distribution at every grid point such as quantiles, expected value, % exceedance

- Incorporation of radar data from non-NEXRAD sources
FLASH v20: Transitioning from deterministic to probabilistic products

- Marginal distributions enable the computation of $\text{Prob}(\text{flood} \mid \text{unitQ})$

March 01, 2018 04 UTC
Example of real-time outputs during Washington DC flash flood emergency (08 July 2019)

Figure 5. The Washington D.C. flash flood event as seen from the deterministic (left) and probabilistic (right) data at 1400 UTC 8 July 2019. The images were taken from the flash.ou.edu web page, which was used during the evaluations. Note that the units for the FLASH CREST Maximum Unit Streamflow product is in metric units (m³ s⁻¹ km⁻²).
Accuracy of MRMS precipitation estimates tied to quality of low-level radar coverage (Chen et al., 2013, *JHM*)

- Studies have shown reduced accuracy with rainfall estimation, tornado and flash flood warnings in radar gaps
- Greatest limitation of NEXRAD-based products is spatial coverage over inter-continental regions and oceans
Options for filling in the radar data voids – Terrestrial-based observations

McLaughlin et al. (2009), *BAMS*

- Use X- and C-band radars as in CASA, Bay Area project, Alamosa radar
  - 100 m gate spacing at low altitudes
  - Integrated network for adaptive scanning
  - Attenuation loss at horizontal incidence
  - Requires partners for sustained O&M

White et al. (2013), *JTECH*
Options for filling in the radar data voids – Airborne radars

**AiRNet:** Airborne Radar Network

**SOES:** Stratospheric Observations of Earth Systems
Airborne Radar Network (AiRNet) – X-band Radars

- A majority of commercial and corporate jets are flying with X-band, scanning radars in their nosecones
- At present, imagery from these radars are displayed in the cockpit for 30 min…and then are discarded

*Any views expressed in this presentation are those of the presenters, and do not necessarily represent the views of the US DOC or NOAA. Presentation of the proposed technology at the 2019 ETW does not constitute an endorsement by NOAA.*
There are ~5000 aircraft over the US during peak operational times!

21-Nov-2018 12:00:01

Accumulated portion of time in a day where there is surveillance by AiRNet within 150 km

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Airborne Radar Network (AiRNet) – Feasibility Study

- Analysis combines operational NEXRAD coverage with the percent of time there is virtual coverage by AiRNet in 24 hr

- Incorporated flight tracks of commercial aircraft and assumed 3D surveillance out to 150 km in range

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FLASH was transitioned to the NWS in 2016 and has advanced the tools for flash flood forecasting in NWS Forecast Offices.

Research continues to improve forcings, models, products:
- Experimentation with precipitation forecasts using NSSL’s Experimental Warn-on-forecast System using Ensembles (NEWS-e)
- Projects (i.e., AiRNet, SOES) initiated to fill in NEXRAD gaps in the West and over oceans
- CREST model state updates with improvements in soil saturation, river stages, snowmelt contribution to runoff
- Entire system being transitioned from deterministic to probabilistic

Additional collaborations welcome!