Quantitative Flood Forecasts using Short-term Radar Nowcasting


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Quantifying Forecast Skill

The predictability of rainfall and flood events is conceptually related to the forecast method and lead time.

Rainfall Predictability

Forecast Lead Time (hours)

Quantifying Flood Forecast Skill

- How does rainfall forecast skill translate to flood forecast skill?
- How do different forecasting methods (persistence or extrapolation) compare in terms of flood prediction?
- Can this skill diagram be quantified for flood prediction?
- What are the effects of lead time and basin scale on flood forecast skill?

Rainfall forecasting using scale-separation extrapolation allows for predictability in the space-time distribution of future rain.

**GDST Nowcasting Model**

- Predictability in rainfall over 0-3 hr over regional, synoptic scales
- Forecast of space-time rainfall evolution suited for linear storm events (e.g. squall lines)
- Tested over ABRFC over 1998-1999 period using NEXRAD, WSI data.
- Skill is a function of lead time, rainfall intensity and verification area.
tRIBS Distributed Hydrologic Model

TIN-based Real-time Integrated Basin Simulator (tRIBS) is a fully-distributed model of coupled hydrologic processes.

Surface-subsurface hydrologic processes over complex terrain.

**tRIBS Hydrologic Processes**

- Coupled vadose and saturated zones with dynamic water table.
- Moisture infiltration waves.
- Soil moisture redistribution.
- Topography-driven lateral fluxes in vadose and groundwater.
- Radiation and energy balance.
- Interception and evaporation.
- Hydrologic and hydraulic routing.
Combined Rainfall-Flood Forecasting

Radar nowcasting and distributed model combined in three modes: Single, Sequential and Batch Forecasts.

(a) Single Forecast Mode
- Utilizes QPEs up to origin ($t_O$)
- Utilizes GDST up to lead time ($t_L$)
- Utilizes $R$ up to end time ($t_F$)

(b) Sequential Forecast Mode
- Multiple QPEs available every $t_L$
- Multi-step ahead GDST QPFs
- Temporal interpolation

(c) Batch Forecast Mode
- Multiple QPEs available frequently
- Single-step ahead GDST QPFs
- Ensemble of equal $t_L$ QPFs

Operational Forecast Modes

- **Single Mode:**
  - Utilizes QPEs up to origin ($t_O$)
  - Utilizes GDST up to lead time ($t_L$)
  - Utilizes $R$ up to end time ($t_F$)

- **Sequential Mode:**
  - Multiple QPEs available every $t_L$
  - Multi-step ahead GDST QPFs
  - Temporal interpolation

- **Batch Mode:**
  - Multiple QPEs available frequently
  - Single-step ahead GDST QPFs
  - Ensemble of equal $t_L$ QPFs
Study Area

Radar rainfall over ABRFC used as forcing to hydrologic model operated over multiple stream gauges in the Baron Fork, OK.

NEXRAD-based Rainfall

- WSI (4-km, 15-min) NOWrad
- GDST nowcasting algorithm
- Transformed to UTM 15
- Clipped to Baron Fork basin

Basin QPFs:

- 808, 107 and 65 km² basins
- 72, 13 and 10 (4 km) radar cells
Basin Data and Interior Gauges

Soils and vegetation distribution used to parameterize tRIBS model. Fifteen gauges used for model flood forecasts.

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Two major flood events: January 4-6, 1998 and October 5-8, 1998 varied in the basin rainfall and runoff response.

**Winter Front:**
- Banded rain accumulation.
- 7-yr flood event at Baron Fork.

**Fall Squall Line:**
- Concentrated rain accumulation.
- Decaying flood wave produced in Dutch Mills.
Multi-Gauge Model Calibration

January 1998

Baron Fork
(808 km²)

Dutch Mills
(107 km²)

October 1998

Peacheater Creek
(65 km²)
Single and Multiple Forecast Modes

Basin-Averaged Rain

Baron Fork QFF

Oct 98

Single Forecast Mode

Sequential Forecast Mode
Forecast Lead-Time Dependence

Flood forecast skill decreases as a function of lead time (Sequential Forecast) for the two storm events.
Catchment Scale Dependence

Flood forecast skill increases as a function of basin area (Sequential Forecast) for the two storm events.
Flood Forecast Skill Comparison

Quantifying the Sequential, Batch and Persistence forecast skill indicates appropriate methods for each lead-time.

- **January 1998**
  - 45 min
  - 21 km²

- **October 1998**
  - 30 min
  - 107 km²
  - 808 km²
**Space-Time Predictability**

Flood predictability using the GDST-tRIBS model identified to scale with a ratio of forecast lead time to basin response time.

**Flood Prediction and Scale**

- For a series of small basins, the lead time ($t_L$) is normalized by the basin time of concentration ($t_C$) in hour.

- $t_C$ obtained using Kirprich formula:
  \[ t_C = 0.000325L^{0.77}S^{-0.385} \]

- $L$ = maximum river length (m) and $S$ = relief ratio (m / m).

- Sharp change in flood forecast skill (Correlation Coefficient $CC$) at $t_L/t_C = 1$

- Indicates high skill of nowcasting in distributed model limited to flash flood events of small, headwater basins.
Final Remarks

Conclusions

(1) GDST nowcasting model enhances flood predictability over 1-3 hours as compared to persistence forecast.

(2) Space-time performance of GDST-tRIBS model suited for flash flood events in small, head water basins.

Additional Analysis

(a) Rainfall-flood error propagation as a function of lead time and basin scale.

(b) Impact of spatial rainfall variability on the flood forecast skill.
Supporting Documentation
Hydrometeorological Flood Events

Two major flood events constituted peak discharge above regulatory limits (Tulsa CoE): Jan 98 (BF, DM), Oct 98 (DM).

563.5 m$^3$/s

283.4 m$^3$/s
Rainfall Variability Dependence

Comparison between basin-averaged GDST forecast and full-radar GDST forecast reveals impact of spatial variability.

Radar vs Mean Areal Precipitation (MAP)

- For 0-2 hours radar QPFs have improved forecast skill (higher CC, lower MAE)
- For 2-3 hours, uniform QPFs have improved forecast skill.
Rainfall-Flood Error Propagation

The tRIBS hydrologic model can augment or dampen errors in GDST rain forecast depending on basin, storm and lead-time.

Error Propagation in Distributed Models

- Bias can amplify or dampen depending on storm and basin.
- Overall, discharge CC higher than rainfall CC.