Operational Paradigm: Uncertainty in Quantitative Precipitation Estimates

Context: QPE use in hydrologic simulations of annual peak flow events

David Streubel- National Weather Service Alaska Pacific River Forecast Center
Kevin Kodama - National Weather Service Honolulu Weather Forecast Office

Abstract

To provide continuous flash flood situational awareness and to better differentiate severity of ongoing individual precipitation events, the National Weather Service Research Distributed Hydrologic Model (RDHM) is being implemented over Hawaii. In the implementation process of RDHM, three gridded precipitation analyses are used as forcing. The first analysis is a radar only precipitation estimate derived from WSR-88D digital hybrid reflectivity, a tropical Z-R relationship and aggregated into an hourly ¼ HRAP grid. The second analysis is derived from a rain gauge network and interpolated into an hourly ¼ HRAP grid using PRISM climatology. The third analysis is derived from rain gauge network where rain gauges are assigned static pre-determined weights to derive a uniform mean areal precipitation that is applied over a catchment on a ¼ HRAP grid. To assess the effect of different QPE analyses on the accuracy of RDHM simulations and to potentially identify a preferred analysis for operational use, each QPE was used to force RDHM to simulate stream flow for 16 USGS peak flow events. An evaluation of the RDHM simulations was focused on peak flow magnitude, peak flow timing, and event volume accuracy to be most relevant for operational use. Results showed RDHM simulations based on the observed rain gauge amounts were more accurate in simulating peak flow magnitude and event volume relative to the radar derived analysis. This result was not consistent for all 16 events nor was it consistent for a few of the rainfall events where an annual peak flow was recorded at more than one gauge. Implications of this may indicate that a more robust QPE forcing with uncertainty derived from the three analyses would provide a better input for simulating operational peak flow events.

Operational Background

Honolulu Weather Forecast Office

- Provides Flash Flood Warnings for Hawaii
- Averages 16 flash flood events a year for the entire state; 1-2 of these may become significant high impact events
- Warning products needs to be issued prior to or during rising limb of hydrograph to be relevant and can contain impact severity information.
- A measure of credibility or uncertainty needs to be available to provide confidence and information for reliable flood products

12/12/2008 Oahu Flood

Alaska Pacific River Center

- Supports Honolulu Weather Forecast office by assisting in implementing models and tools to provide flood situational awareness and forecast capabilities.
- To be relevant, measures of model performance and or uncertainty needs to be established prior to operational implementation.

Project

- Implement HL-RDHM [1] hydrologic model with focus on annual peak flow simulations at USGS gages
- Assess model simulation performance for complex terrain relative to three different operational gridded precipitation estimates used by NWS.
- Determine optimal operational QPE analysis based on simulation performance or make steps to derive operational procedure to incorporate more than one QPE analysis if results indicate value
- Derive general conclusions on the effect of QPE analysis uncertainty for RDHM simulations of USGS peak flow events. If possible incorporate QPE uncertainty into future operational use of RDHM during extreme precipitation events.

Methodology

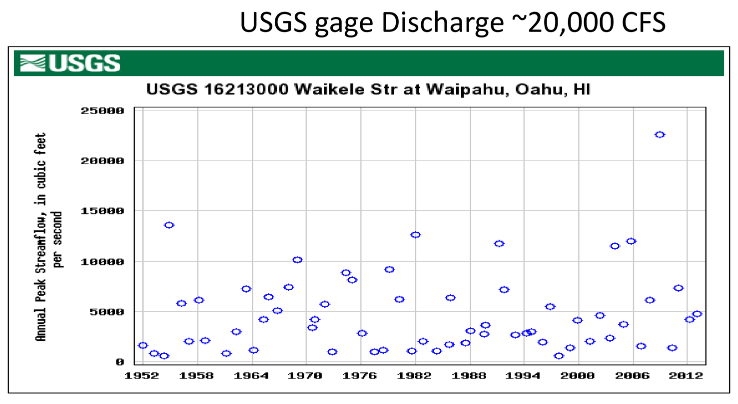
- HL-RDHM[1] implemented using a-priori parameters in basins with USGS gages on Kauai and Oahu. Evaluation focused on four basins
  - Hanalei River; Basin Area 18.5 mi^2
  - SF Wailua River; Basin Area 23.7 mi^2
  - Waikele Stream; Basin Area 45.1 mi^2
  - Manoa Stream; Basin Area 5.8. mi^2
- Gridded 1hr QPE derived from 2000-2011 for island of Kauai and Oahu using three different approaches
  - Mountain Mapper[2]: A precipitation gauge analysis using PRISM interpolation aggregated to ~1km grid mesh
  - DHR(HPE) Analysis: WSR-88D digital hybrid reflectivity product is used with tropical Z-R equation to generate a gridded precipitation estimate at a ~1KM mesh
  - Pre-determined weights [3]: uniform catchment precipitation estimate is derived from annual water balance using USGS stream flow runoff data, estimate of ET, and rain gauge data

- To be relevant, NWS operations accuracy of HL-RDHM simulation with respect to each QPE forcing was assessed with focus on peak flow magnitude, timing, and event volume.

Waikele Stream and at USGS gage Discharge < 50 CFS

Waikele stream 12/12/2008 at USGS gage Discharge ~20,000 CFS

- To try and determine which QPE may be preferred for operational use and to get better understanding of how consistent RDHM simulations performed relative to QPE source, 16 peak flow events were simulated for 4 USGS gages and results were ranked relative to one another.

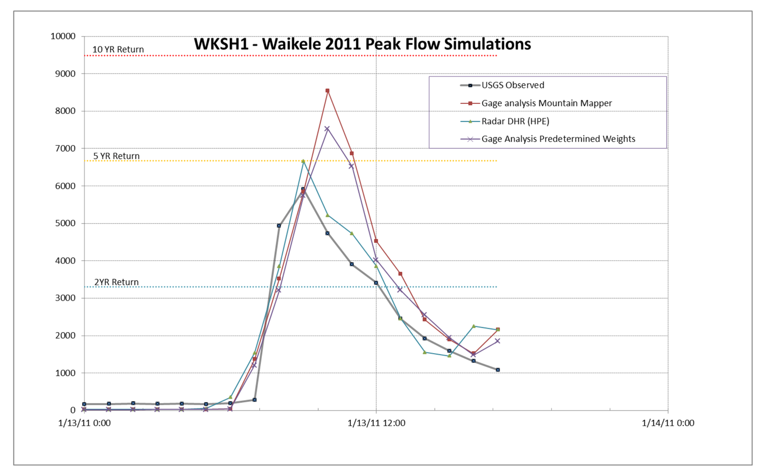


RDHM evaluated on USGS annual peak flow events rather than other aspects of the annual hydrograph.

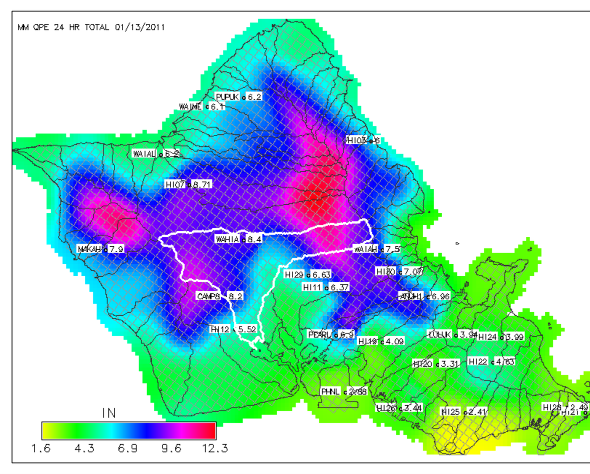
Results

➢ Example 1- Waikele Stream Peak Flow Event 1/13/2011: HL-RDHM Simulations

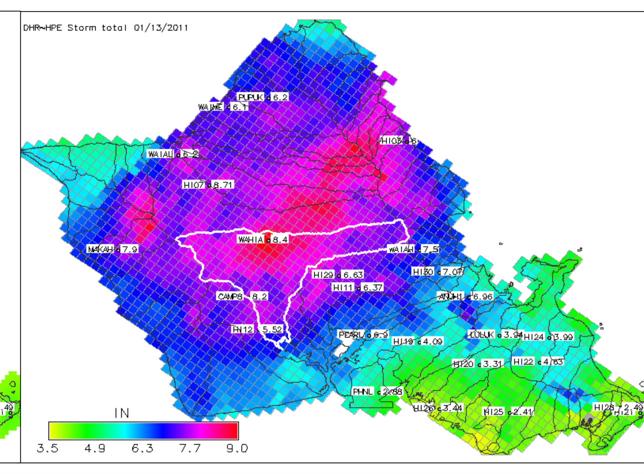
	Peak Flow (CFS) *top of HR	Peak Timing (HRs from OBS)	Basin Precipitation (IN)	Basin Runoff (IN)
USGS OBS	5910			4.5
RDHM QPE MTN Map	8540	+1	10.1	7.1
RDHM QPE DHR	6660	0	8.2	5.7
RDHM QPE PRE DET	7520	+1	9.0	6.1



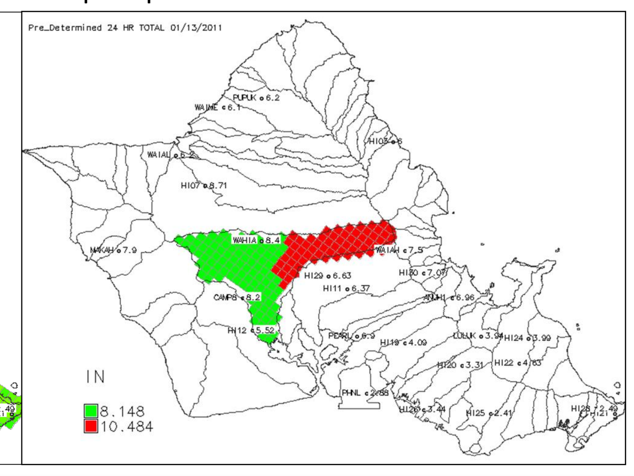
Mountain Mapper Storm Total Precipitation



DHR-HPE storm total precipitation

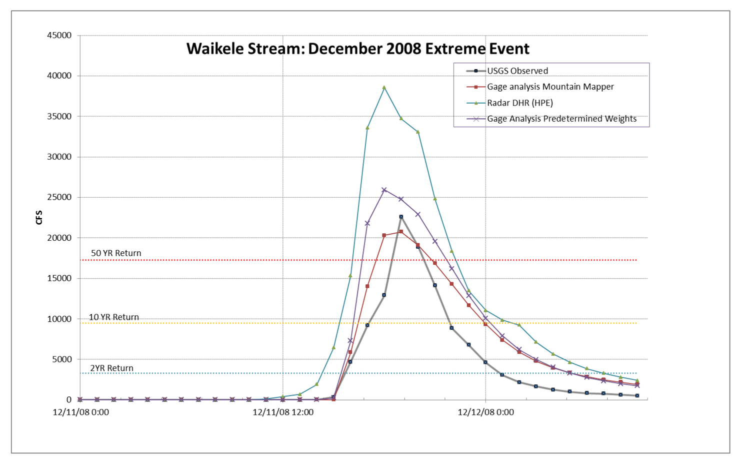


Pre-determined weight storm total precipitation

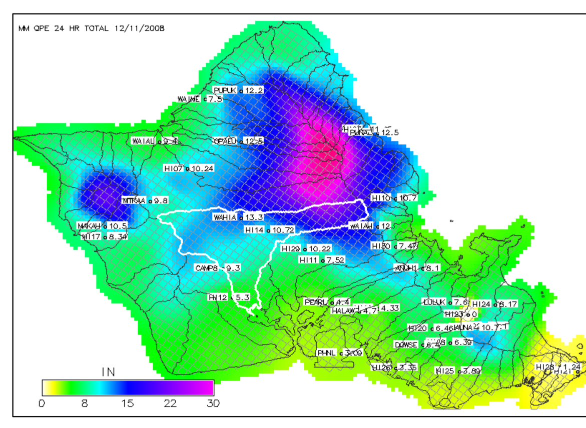


➢ Example 2- Waikele Stream Peak Flow Event 12/12/2008: HL-RDHM Simulations

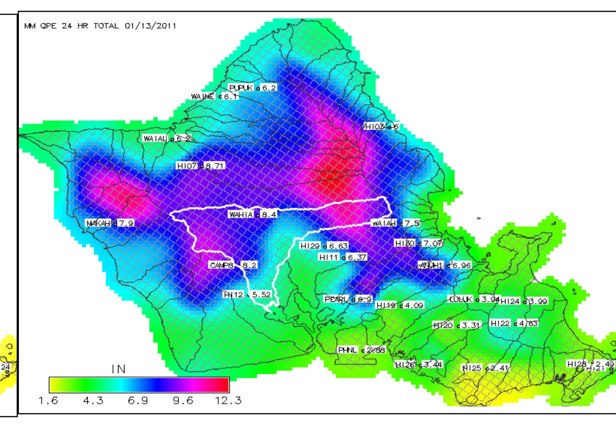
	Peak Flow (CFS) *top of HR	Peak Timing (HRs from OBS)	Catchment Precipitation (IN)	Basin Runoff (IN)
USGS OBS	22600			6.2
RDHM QPE MTN Map	20300	0	11.1	8.6
RDHM QPE DHR	38500	-1	16.0	14.5
RDHM QPE PRE DET	25900	-1	12.9	10.1



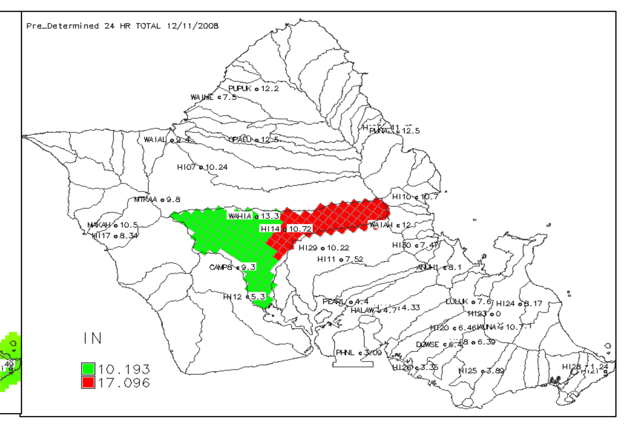
Mountain Mapper Storm Total Precipitation



DHR-HPE storm total precipitation



Pre-determined weight storm total precipitation



➢ Tables shows relative ranked results of event simulations forced with each QPE analysis. For peak flow and event volume smaller rank is given to analysis that simulated closest to USGS observed. Timing rank is difference in simulated peak hour from USGS observed peak hour.

Table 1: Peak Flow Rank

USGS Event	MM	DHR	PRE
Manoa Stream 03/2009	1	3	2
Manoa Stream 11/2009	2	3	1
Manoa Stream 12/2010	3	1	2
Manoa Stream 10/2004	1	*	2
Waikele Str 11/2007	1	3	2
Waikele Str 12/2008	1	3	2
Waikele Str 04/2010	2	3	1
Waikele Str 01/2011	3	1	2
Hanalei River 12/2007	1	3	2
Hanalei River 07/2009	2	3	1
Hanalei River 11/2009	2	3	1
Hanalei River 5/2011	1	3	2
SF Wailua 12/2007	1	2	3
SF Wailua 12/2008	2	1	3
SF Wailua 11/2009	3	1	2
SF Wailua 05/2011	3	1	2
SUM	26	34	28

Table 2: Peak Flow Timing Rank

USGS Event	MM	DHR	PRE
Manoa Stream 03/2009	0	0	0
Manoa Stream 11/2009	1	0	1
Manoa Stream 12/2010	1	1	1
Manoa Stream 10/2004	0	*	1
Waikele Str 11/2007	2	1	2
Waikele Str 12/2008	0	1	1
Waikele Str 04/2010	2	3	1
Waikele Str 01/2011	1	0	1
Hanalei River 12/2007	1	3	2
Hanalei River 07/2009	2	3	1
Hanalei River 11/2009	1	2	1
Hanalei River 5/2011	1	3	2
SF Wailua 12/2007	1	2	2
SF Wailua 12/2008	2	1	2
SF Wailua 11/2009	2	1	2
SF Wailua 05/2011	2	1	2
	19	21	22

Table 3: Event Volume Rank

USGS Event	MM	DHR	PRE
Manoa Stream 03/2009	1	3	2
Manoa Stream 11/2009	1	3	2
Manoa Stream 12/2010	3	2	1
Manoa Stream 10/2004	1	*	2
Waikele Str 11/2007	1	3	2
Waikele Str 12/2008	1	3	2
Waikele Str 04/2010	2	3	1
Waikele Str 01/2011	3	1	2
Hanalei River 12/2007	2	3	1
Hanalei River 07/2009	2	3	1
Hanalei River 11/2009	2	3	1
Hanalei River 5/2011	1	3	2
SF Wailua 12/2007	1	2	3
SF Wailua 12/2008	1	2	2
SF Wailua 11/2009	3	1	2
SF Wailua 05/2011	1	2	3
	27	37	28

Conclusions & Future Consideration..

- Rain gauge based analyses generally had less bias in the magnitude of the peak flow event and event volume for the 16 peak flow events than the radar based analysis. The result was not consistent for every event and to each basin. For peak flow timing, no analysis appeared to consistently outperform the others.
- Operational skill of RDHM to accurately identify and simulate extreme events will likely be lower if only one operational QPE analysis is used. This needs to be considered over bigger NWS operational scales and in context to efforts to create an "optimum" operational QPE.
- The "optimum" gridded QPE analysis for peak flow event simulations should contain uncertainty and potentially a tool to derive and include an ensemble of QPE to create more realistic hydrologic model states and better represent simulation uncertainty.

References

[1] Schaake, J., Henkel, A., Cong, S. (2004) "Application of PRISM Climatologies for Hydrologic Modeling and Forecast in the Western U.S. Tech Memorandum; Conference of Hydrology, 84th Annual American Meteorological Association Conference.
[2] Koren, V., Reed, S., Smith, M., Zhang, Z., Seo, D.-j., 2004. Hydrology laboratory research modeling system (HL-RMS) of the US National Weather Service. Journal of Hydrology 291, 297-318.
[3] Anderson E, "Steps to Follow When Computing Mean Areal Precipitation for Model Calibration" National Weather Service River Forecast System User Manual. Part 4.