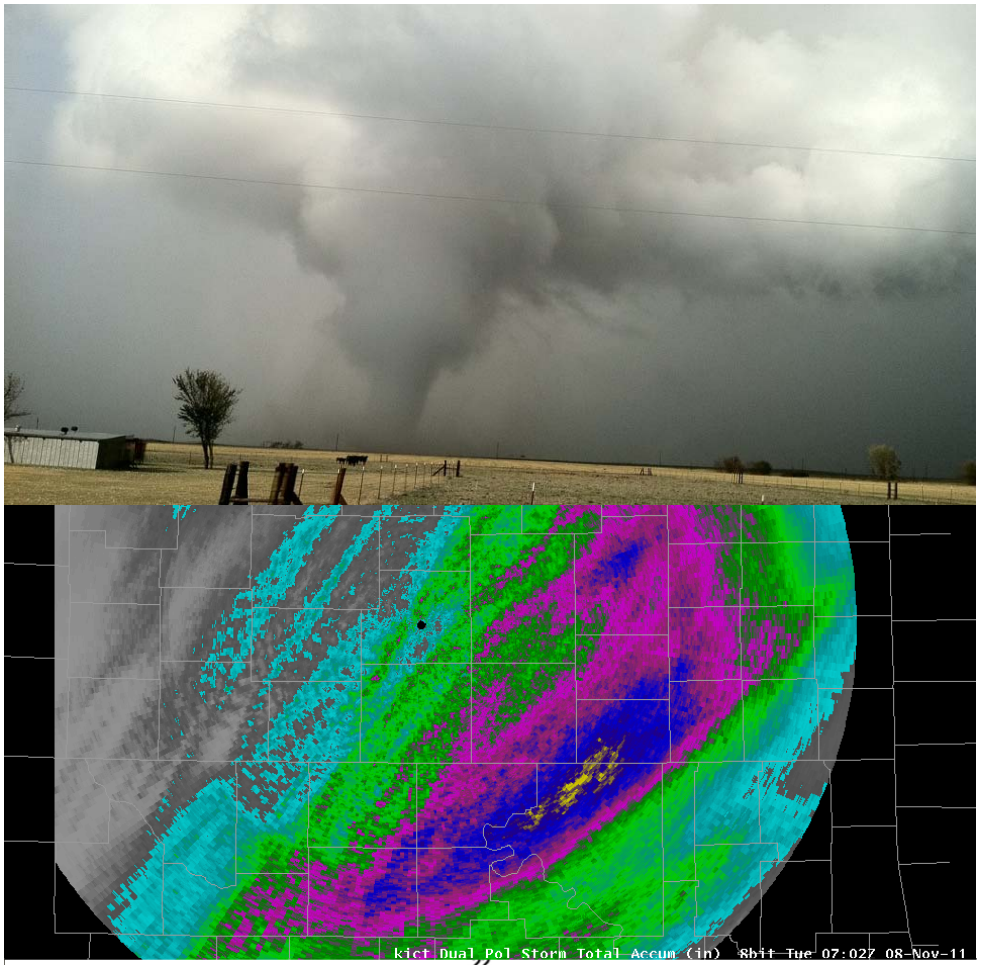
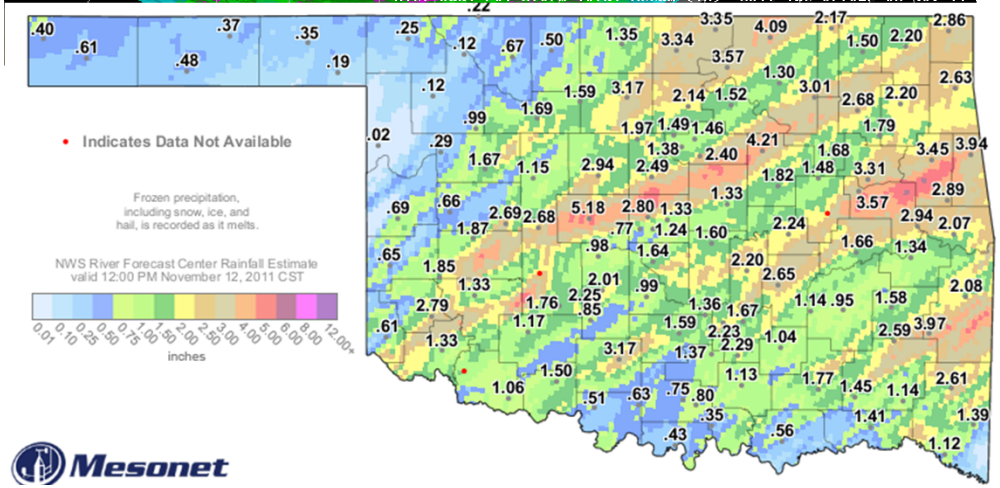




Dual Pol Quantitative Precipitation Estimate Verification

Lt Col Steve Cocks

Radar Operations Center

TAC Meeting

01 March, 2012

OVERVIEW

- **Verification Process**
- **KOUN/KVNX/KMHX/KICT Results**
- **Current DP QPE Work**
- **Summary**

Verification Process

- Compared Dual Pol. Quantitative Precipitation Estimate (DP QPE) & legacy Precipitation Processing System (PPS) storm total rain estimates to rain gauge data at four radars

- Statistical measures used to evaluate DP QPE & PPS performance:
  - Root Mean Square Errors (RMSE)
  - Bias (Radar estimate minus gauge total)
  - Non-Parametric statistical tests to determine significance

- KOUN, Norman, OK: 10 cases; 809 radar est./gauge (R/G) pairs

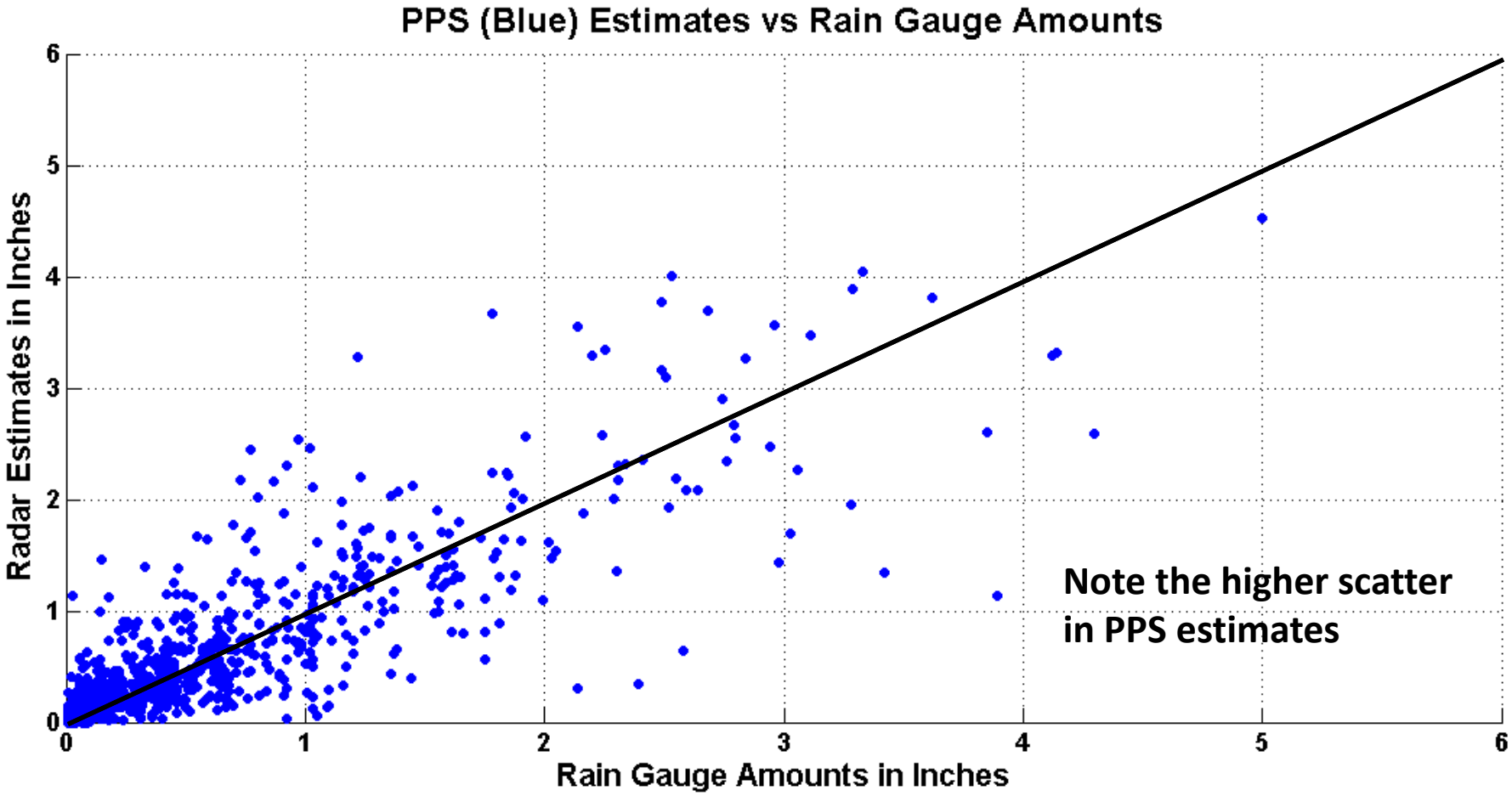
- KVNX, Vance AFB, OK: 14 cases; 612 R/G pairs

- KMHX, Morehead City, NC: 7 cases; 670 R/G pairs (No Irene data)

- KICT, Wichita, KS: 7 cases; 807 R/G pairs

KOUN RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 809,	PPS RMSE = 0.45”	DP RMSE = 0.37”	YES
Gauges > 0.5”:	R/G = 344,	PPS RMSE = 0.62”	DP RMSE = 0.52”	YES
Gauges > 1.0”:	R/G = 178,	PPS RMSE = 0.79”	DP RMSE = 0.60”	YES
Gauges > 2.0”:	R/G = 49,	PPS RMSE = 1.21”	DP RMSE = 0.84”	YES



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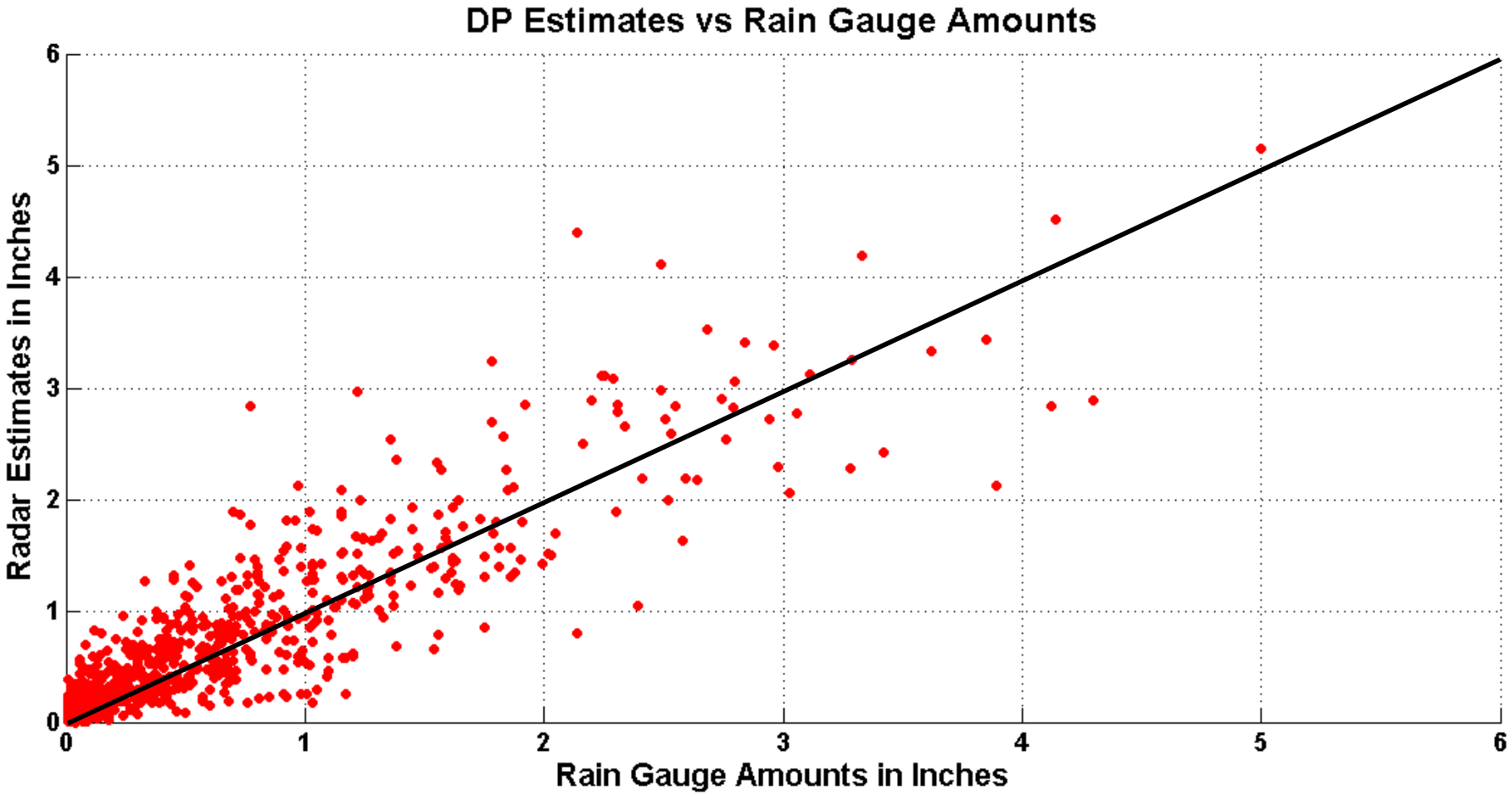
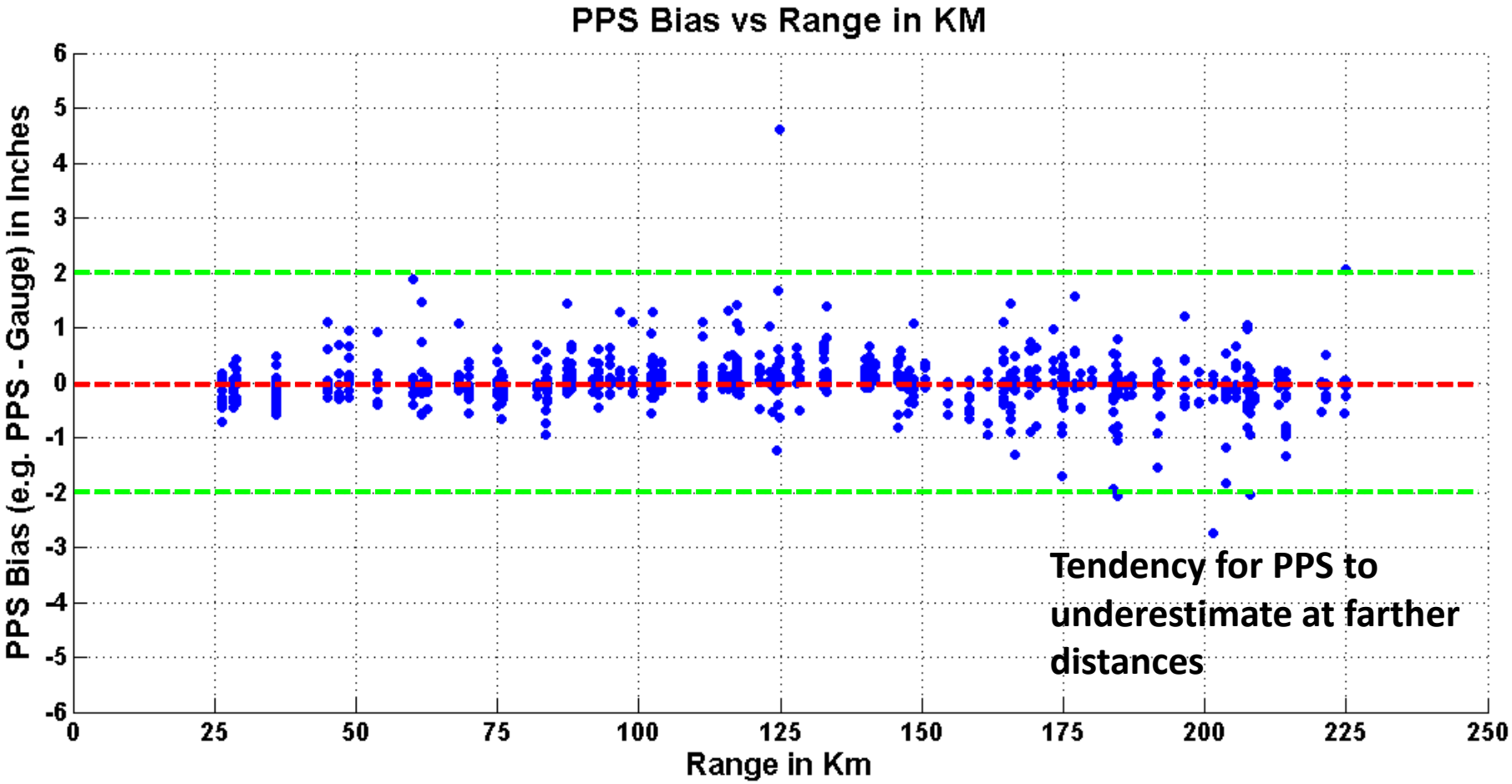
Gauges > 0.5”:	R/G = 344,	PPS RMSE = 0.62”	DP RMSE = 0.52”	YES
Gauges > 1.0”:	R/G = 178,	PPS RMSE = 0.79”	DP RMSE = 0.60”	YES
Gauges > 2.0”:	R/G = 49,	PPS RMSE = 1.21”	DP RMSE = 0.84”	YES



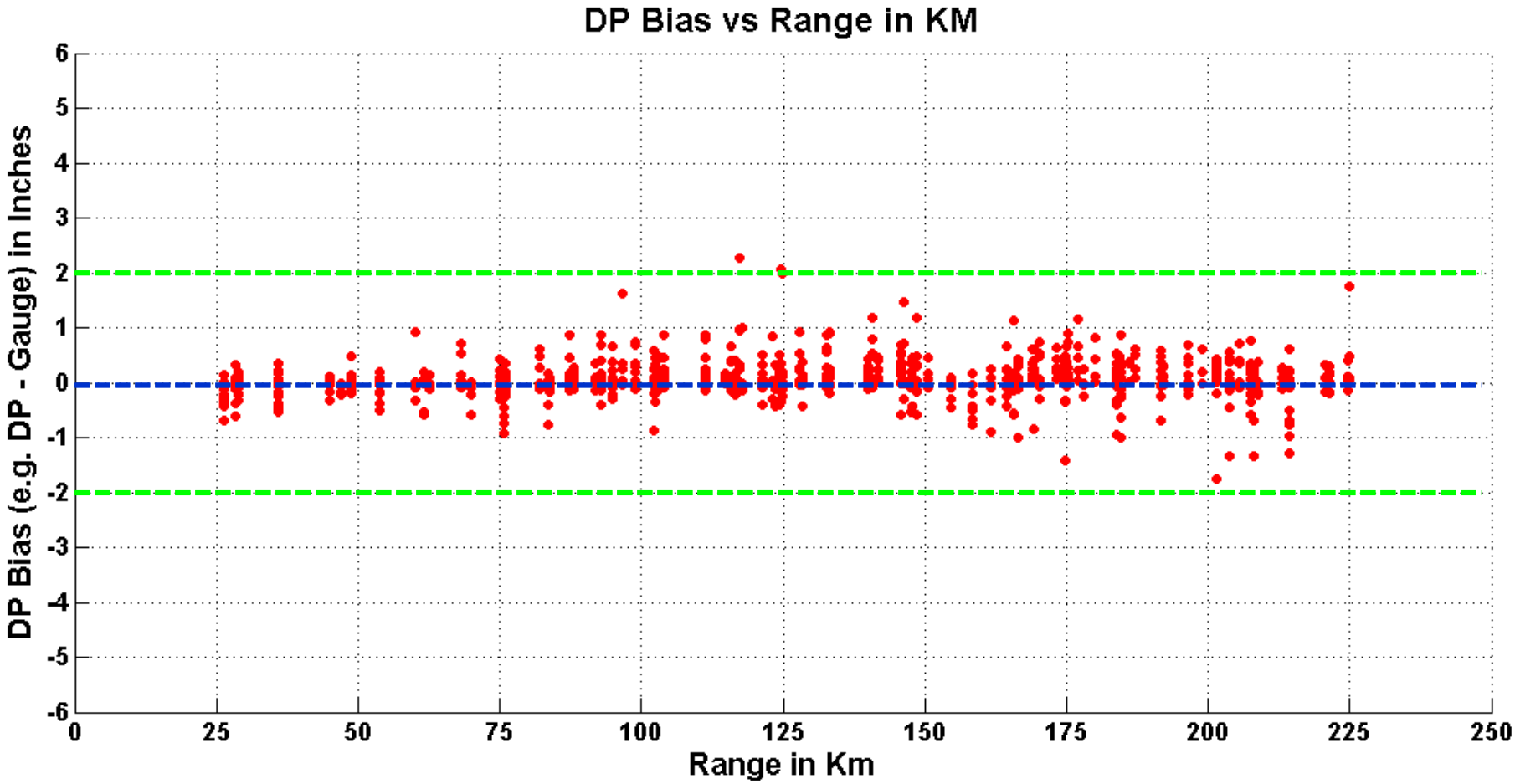
KOUN RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 809,	PPS Bias = 0.01”	DP Bias = 0.07”	YES
Gauges > 0.5”:	R/G = 344,	PPS Bias = -0.06”	DP Bias = 0.06”	YES
Gauges > 1.0”:	R/G = 178,	PPS Bias = -0.13”	DP Bias = 0.01”	YES
Gauges > 2.0”:	R/G = 49,	PPS Bias = -0.21”	DP Bias = -0.02”	YES



KOUN RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 809,	PPS Bias = 0.01”	DP Bias = 0.07”	YES
Gauges > 0.5”:	R/G = 344,	PPS Bias = -0.06”	DP Bias = 0.06”	YES
Gauges > 1.0”:	R/G = 178,	PPS Bias = -0.13”	DP Bias = 0.01”	YES
Gauges > 2.0”:	R/G = 49,	PPS Bias = -0.21”	DP Bias = -0.02”	YES

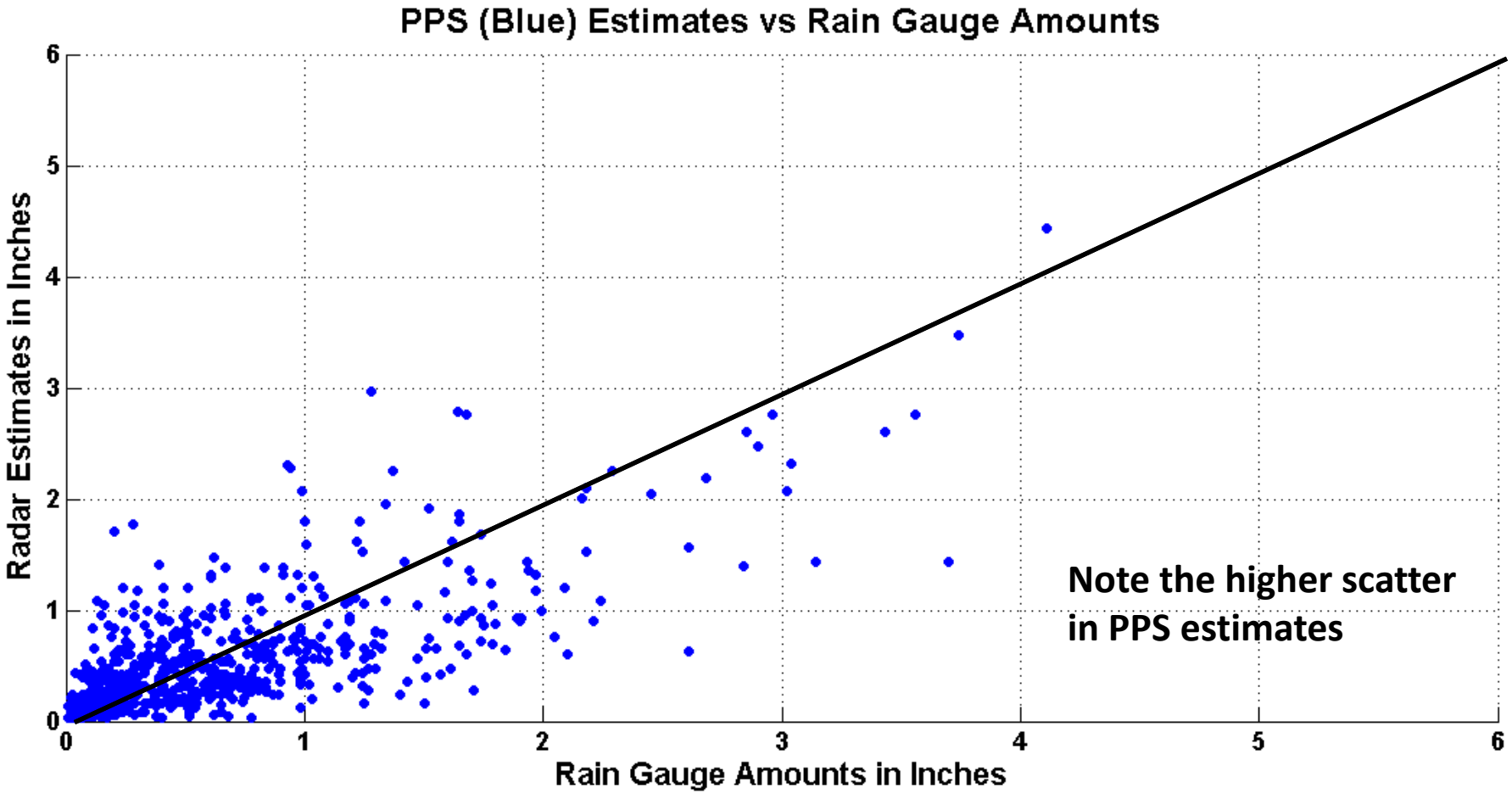


KVNX Results

- **KVNX data analysis showed similar performance trends as seen in KOUN:**
  - **DP QPE RMSE values significantly smaller than PPS**
    - **Degree of improvement DP provides over PPS increases with higher rainfall totals**
  - **DP QPE Bias values slightly higher than PPS for lighter rain amounts (< = 1”)**

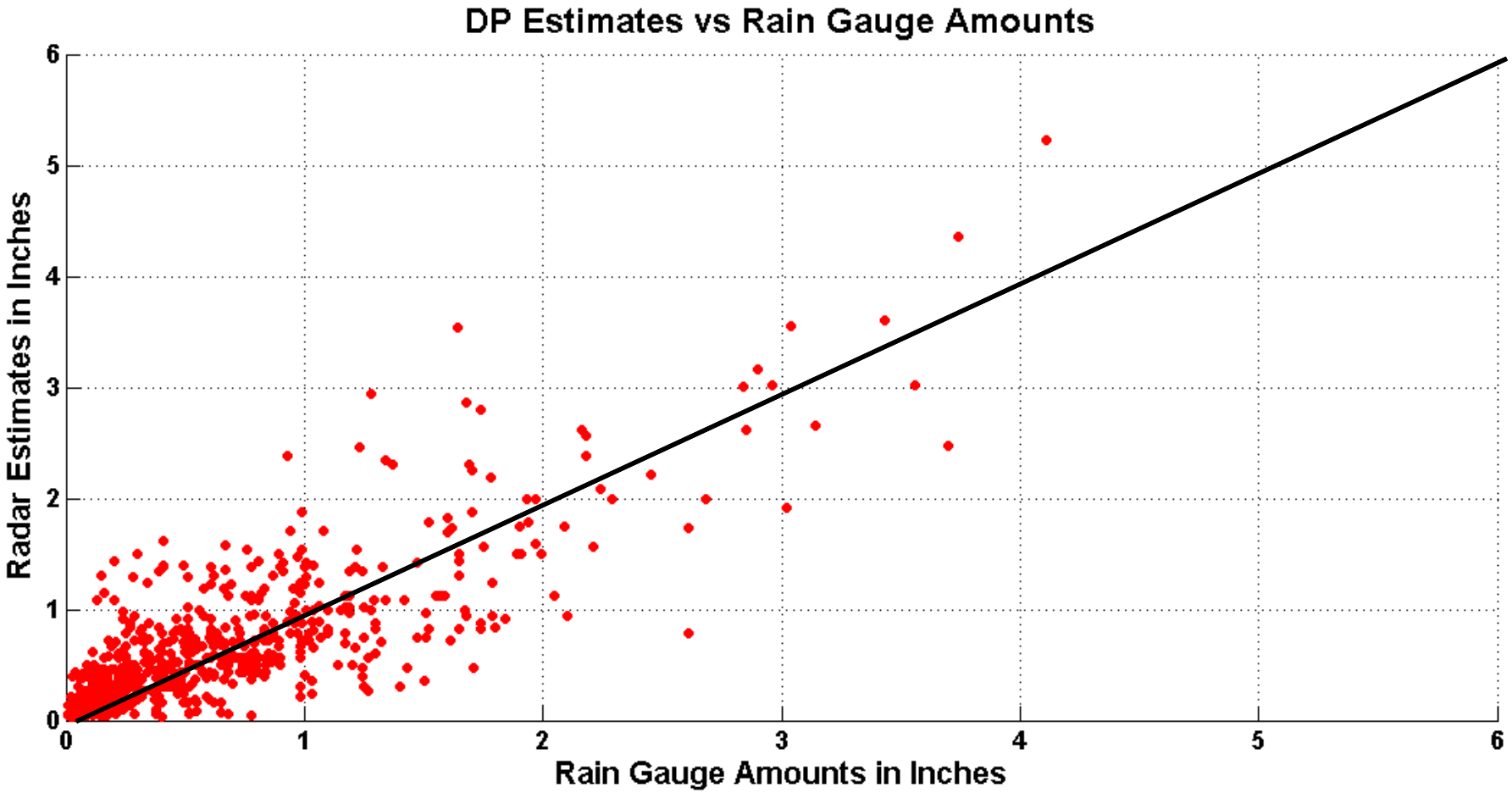
KMHX RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 670,	PPS RMSE = 0.45”	DP RMSE = 0.39”	YES
Gauges > 0.5”:	R/G = 313,	PPS RMSE = 0.59”	DP RMSE = 0.49”	YES
Gauges > 1.0”:	R/G = 130,	PPS RMSE = 0.79”	DP RMSE = 0.64”	YES
Gauges > 2.0”:	R/G = 65,	PPS RMSE = 1.04”	DP RMSE = 0.73”	YES



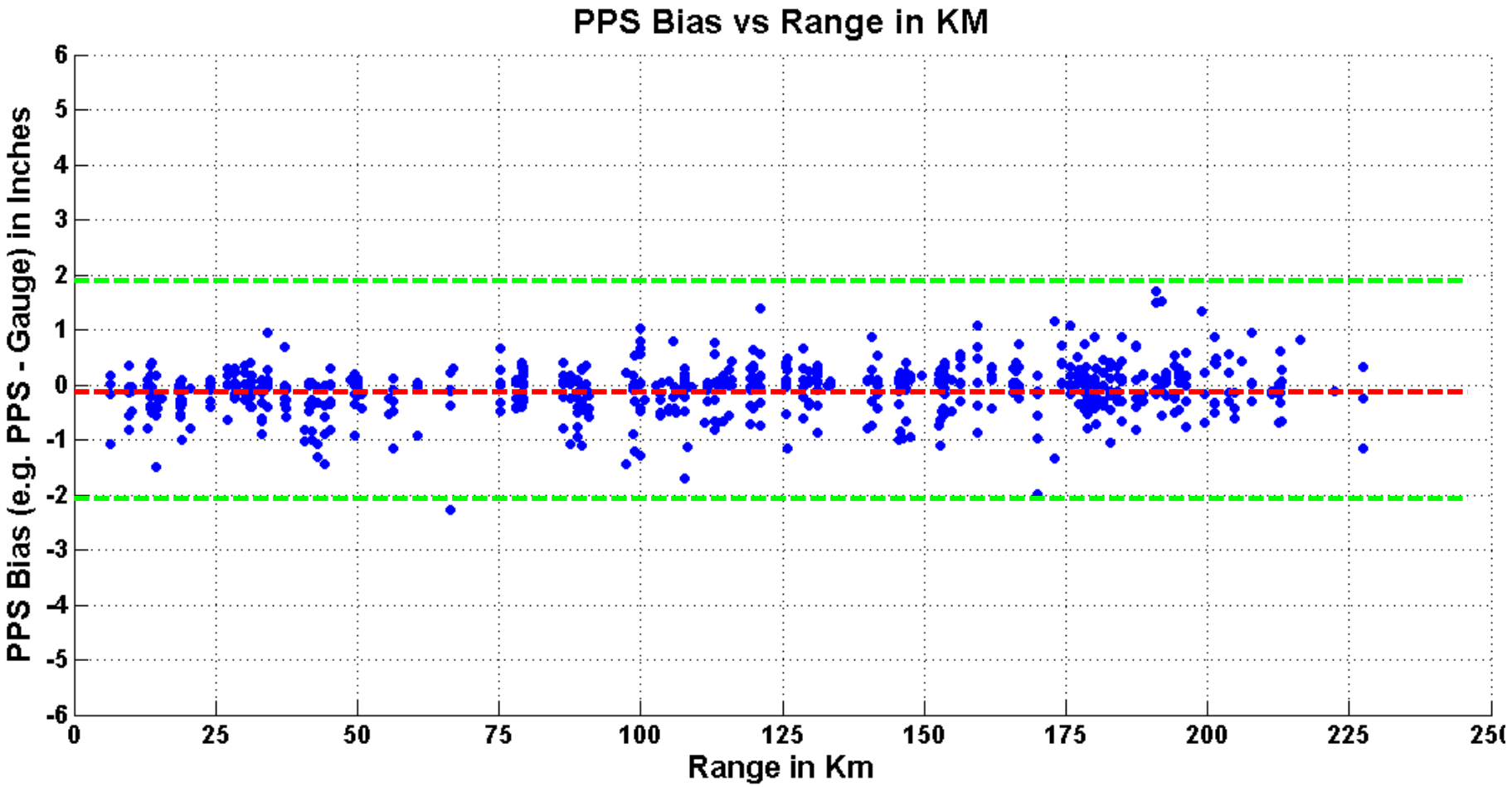
KMHX RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 670,	PPS RMSE = 0.45”	DP RMSE = 0.39”	YES
Gauges > 0.5”:	R/G = 313,	PPS RMSE = 0.59”	DP RMSE = 0.49”	YES
Gauges > 1.0”:	R/G = 130,	PPS RMSE = 0.79”	DP RMSE = 0.64”	YES
Gauges > 2.0”:	R/G = 65,	PPS RMSE = 1.04”	DP RMSE = 0.73”	YES



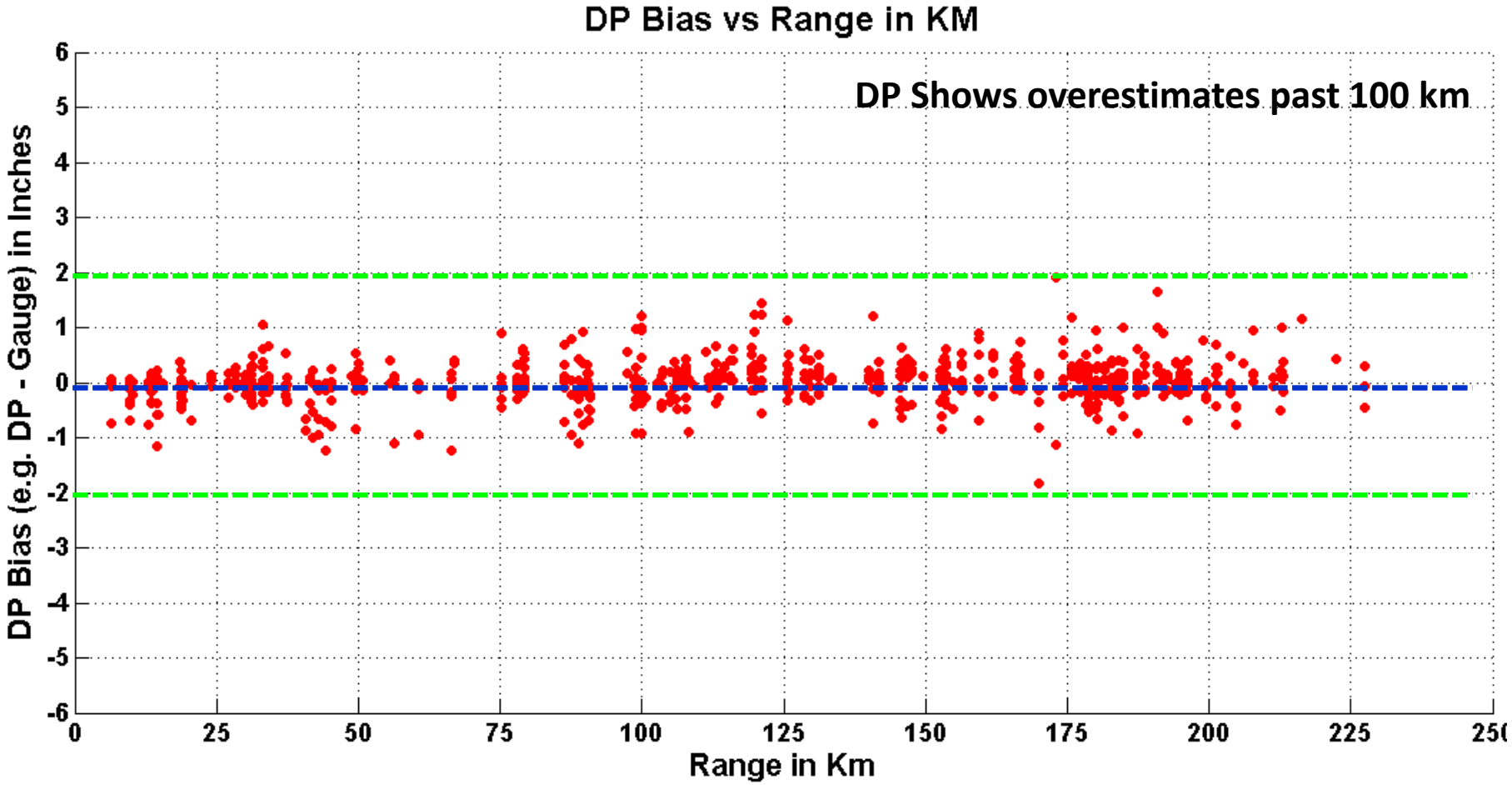
KMHX RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 670,	PPS Bias = -0.09”	DP Bias = 0.03”	NO
Gauges > 0.5”:	R/G = 313,	PPS Bias = -0.31”	DP Bias = -0.09”	YES
Gauges > 1.0”:	R/G = 130,	PPS Bias = -0.52”	DP Bias = -0.22”	YES
Gauges > 2.0”:	R/G = 25,	PPS Bias = -0.82”	DP Bias = -0.27”	YES



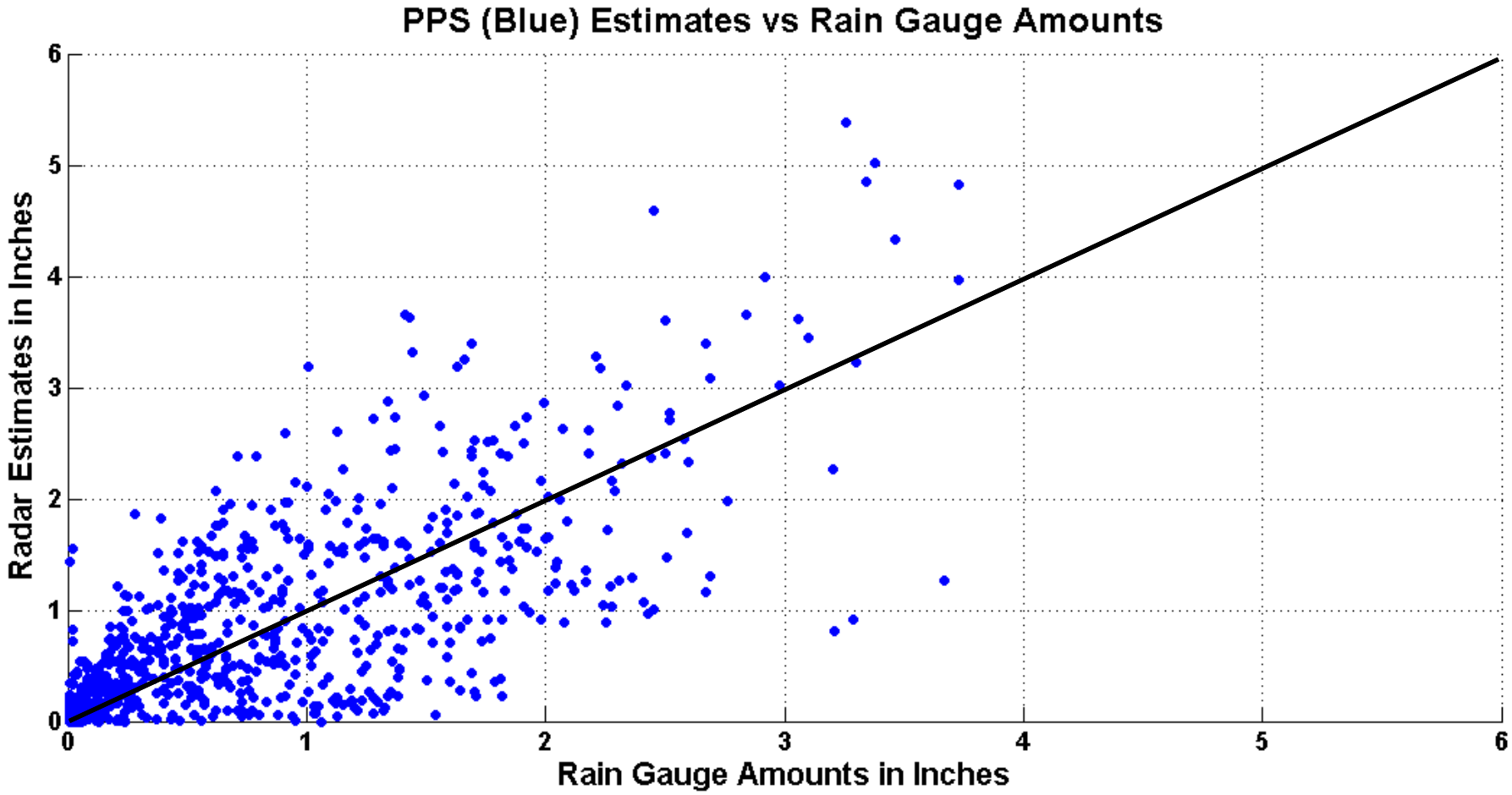
KMHX RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 670,	PPS Bias = -0.09”	DP Bias = 0.03”	YES
Gauges > 0.5”:	R/G = 313,	PPS Bias = -0.31”	DP Bias = -0.09”	YES
Gauges > 1.0”:	R/G = 130,	PPS Bias = -0.52”	DP Bias = -0.22”	YES
Gauges > 2.0”:	R/G = 25,	PPS Bias = -0.82”	DP Bias = -0.27”	YES



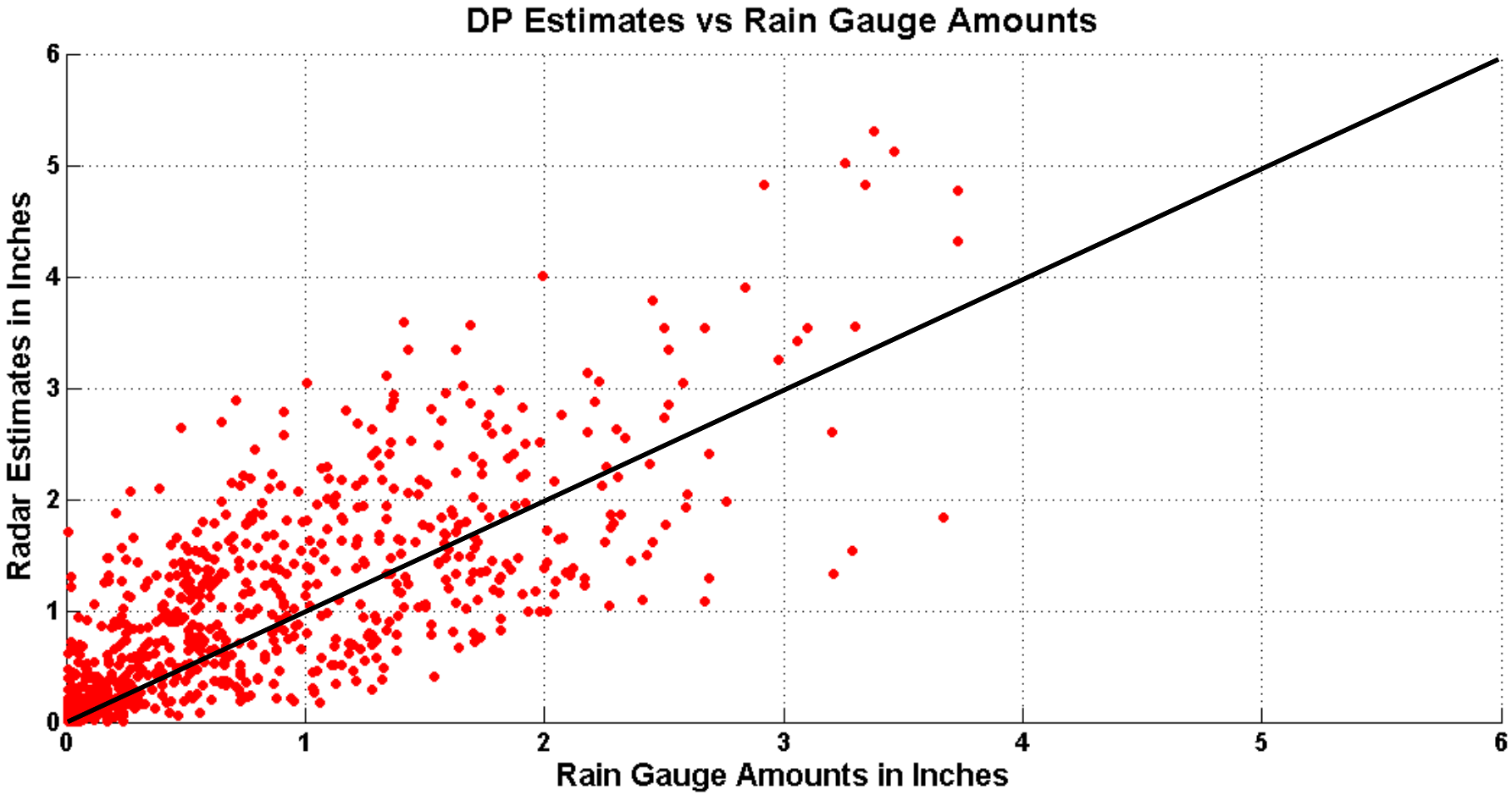
KICT RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 807,	PPS RMSE = 0.62”	DP RMSE = 0.64”	NO
Gauges > 0.5”:	R/G = 451,	PPS RMSE = 0.77”	DP RMSE = 0.76”	NO
Gauges > 1.0”:	R/G = 270,	PPS RMSE = 0.87”	DP RMSE = 0.80”	YES
Gauges > 2.0”:	R/G = 65,	PPS RMSE = 1.03”	DP RMSE = 0.93”	YES



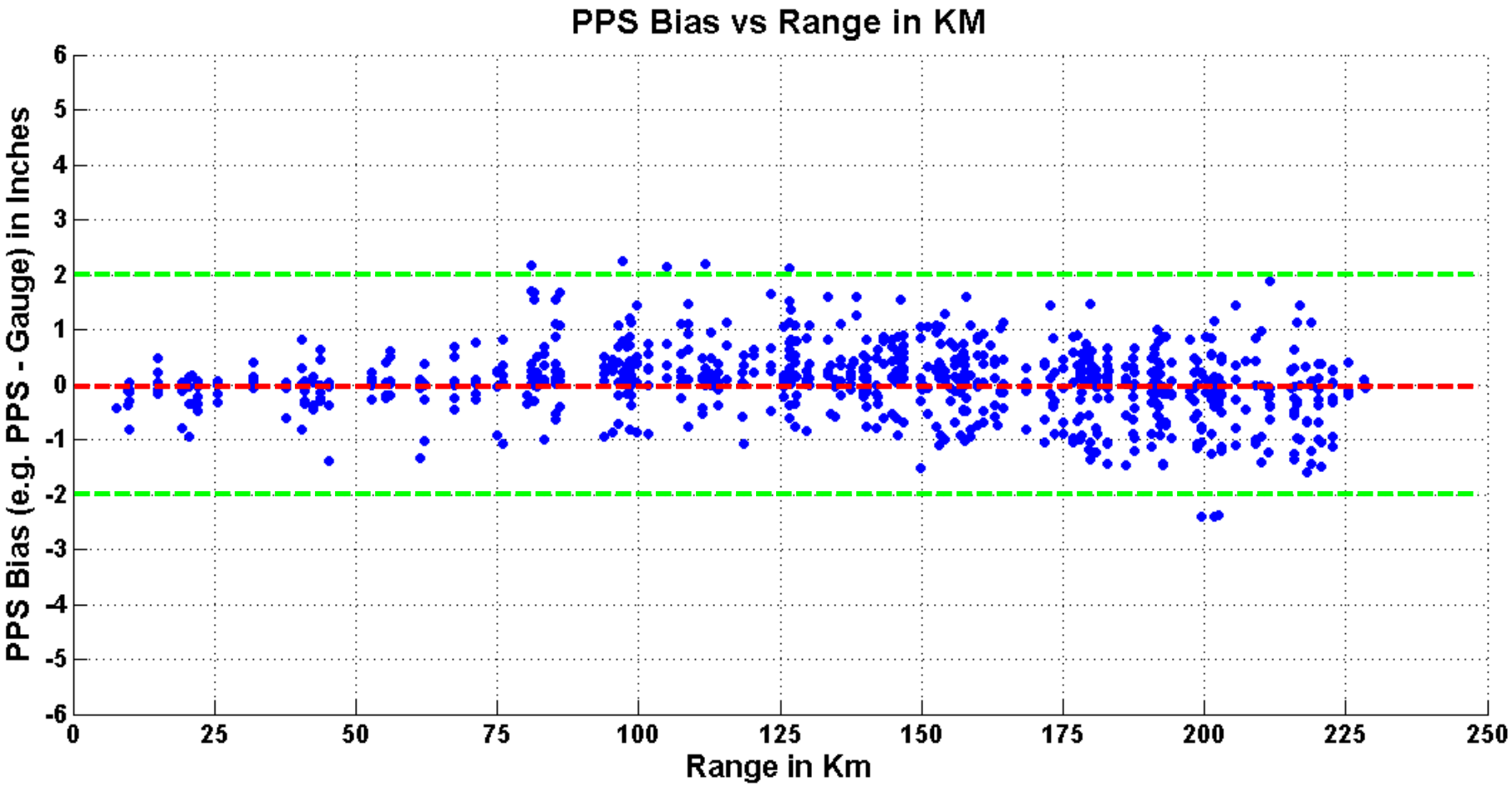
KICT RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 807,	PPS RMSE = 0.62”	DP RMSE = 0.64”	NO
Gauges > 0.5”:	R/G = 451,	PPS RMSE = 0.77”	DP RMSE = 0.76”	NO
Gauges > 1.0”:	R/G = 270,	PPS RMSE = 0.87”	DP RMSE = 0.80”	YES
Gauges > 2.0”:	R/G = 65,	PPS RMSE = 1.03”	DP RMSE = 0.93”	YES



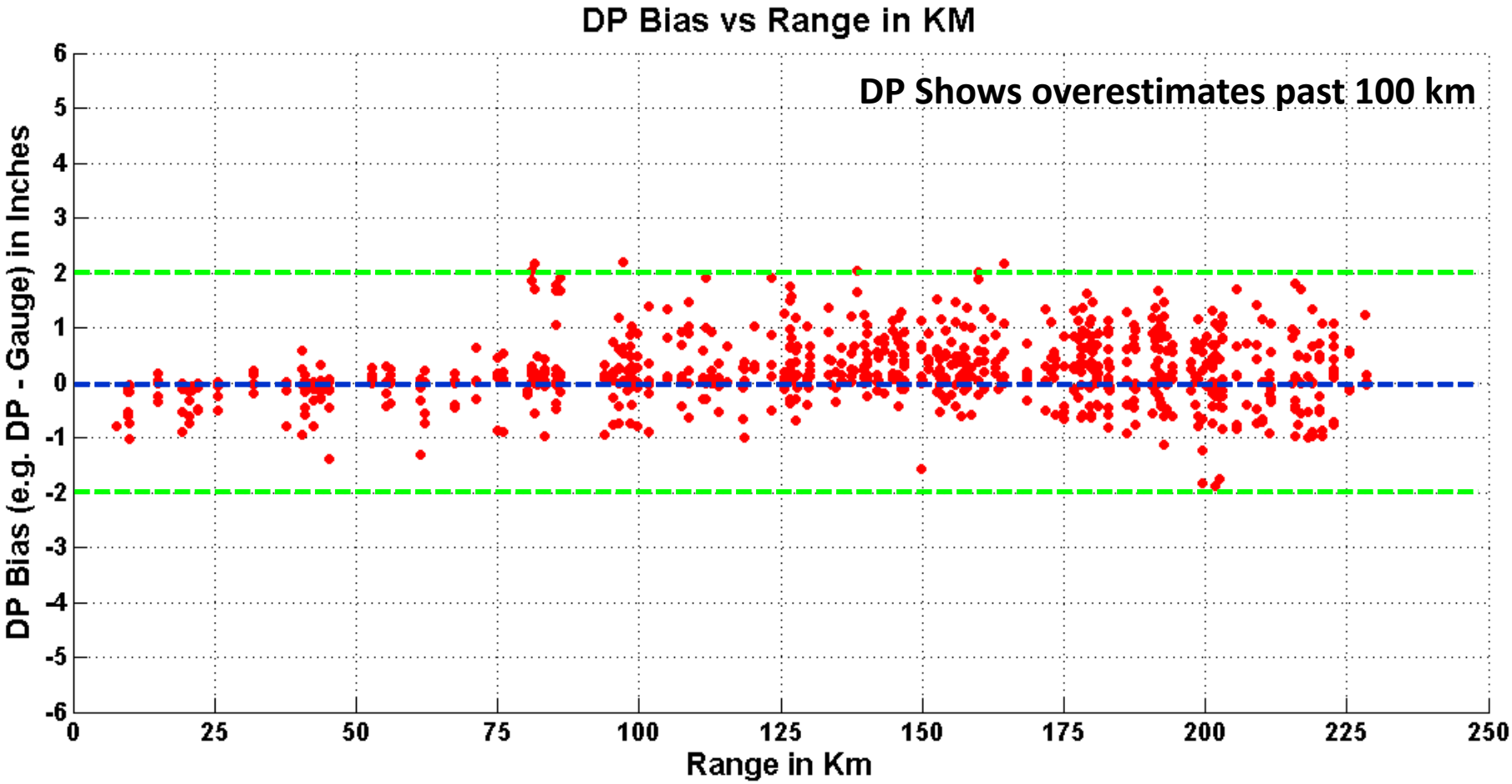
KICT RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 807,	PPS Bias = 0.05”	DP Bias = 0.21”	YES
Gauges > 0.5”:	R/G = 451,	PPS Bias = -0.06”	DP Bias = 0.19”	YES
Gauges > 1.0”:	R/G = 270,	PPS Bias = -0.19”	DP Bias = 0.08”	YES
Gauges > 2.0”:	R/G = 65,	PPS Bias = -0.25”	DP Bias = -0.12”	YES



KICT RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 807,	PPS Bias = 0.05”	DP Bias = 0.21”	YES
Gauges > 0.5”:	R/G = 451,	PPS Bias = -0.06”	DP Bias = 0.19”	YES
Gauges > 1.0”:	R/G = 270,	PPS Bias = -0.19”	DP Bias = 0.08”	YES
Gauges > 2.0”:	R/G = 65,	PPS Bias = -0.25”	DP Bias = -0.12”	YES



RADAR RESULTS FOR R/G PAIRS > 150km

Radar	Category	Obs.	Bias Errors		Stat. Sig.
KICT	Gauges ≤ 1.0”:	R/G = 388,	PPS Bias = 0.13”	DP Bias = 0.38”	YES
	Gauges > 1.0”:	R/G = 119,	PPS Bias = -0.59”	DP Bias = -0.04”	YES
KOUN	Gauges ≤ 1.0”:	R/G = 254,	PPS Bias = 0.02”	DP Bias = 0.14”	YES
	Gauges > 1.0”:	R/G = 54,	PPS Bias = -0.61”	DP Bias = 0.30”	YES
KVNX	Gauges ≤ 1.0”:	R/G = 214,	PPS Bias = 0.11”	DP Bias = 0.25”	YES
	Gauges > 1.0”:	R/G = 72,	PPS Bias = -0.25”	DP Bias = 0.06”	YES
KMHX	Gauges ≤ 1.0”:	R/G = 198,	PPS Bias = 0.06”	DP Bias = 0.11”	NO
	Gauges > 1.0”:	R/G = 37,	PPS Bias = -0.25”	DP Bias = -0.08”	NO

Suspect higher DP bias for lighter rain amounts related to DP challenges of estimating rainfall in Melting Layer (ML)

DP QPE PERFORMANCE DISCUSSION

- **Melting Layer (ML) Likely Source of KICT DP Bias Errors:**
  - **DP QPE estimates based on classification of radar echoes in three regions:**
    - **Above ML where all precipitation is frozen**
    - **In ML, where precipitation transitions from frozen to liquid**
    - **Below ML where precipitation is all liquid**
  - **Below ML, DP QPE primarily uses DP variables to estimate rain**
  - **In and above ML, DP QPE primarily a function of the default PPS Z-R relationship (R(Z))**
    - **Example: for Wet Snow, *DP QPE Rain Rate = 0.6*PPS Estimate (e.g. R(Z))***

DP QPE PERFORMANCE DISCUSSION

- **Melting Layer Likely Source of KICT DP Bias Errors *Cont.*:**
  - **Echoes classified as dry snow in/abv ML likely surface light rain**
    - **If in ML, echo classified as Dry Snow, *DP QPE Rain Rate = R(Z)***
    - **If above ML, echo classified as Dry Snow or Ice Crystals, *DP QPE Rain Rate = 2.8*R(Z)***

  - ***Result: DP QPE radar estimates made in the ML likely are being overestimated during light precipitation events***
    - **WFOs have reported similar trend at KPBX and KCLE**
    - **Further analysis needed to develop methods to mitigate this effect, especially for different climatic regimes**

CURRENT WORK

- **The ROC Applications Branch, NWS Office of Science/Technology and NSSL personnel working together to:**
  - **Evaluate DP QPE and PPS performance for DP radars in different climatic regimes in the U.S. as additional radars are upgraded**
  - **Document performance of deployed DP QPE algorithm**
  - **Fine tune algorithm code to improve performance**

- **NSSL currently developing more robust Hydro-Meteorological Classification (HCA) algorithm for cool season**
  - **Should improve DP QPE rain estimates during cooler weather regimes**

- **Efforts to mature the DP QPE & other DP algorithms will be a multi-year process**
  - **Challenge to improve DP QPE algorithm is top priority**

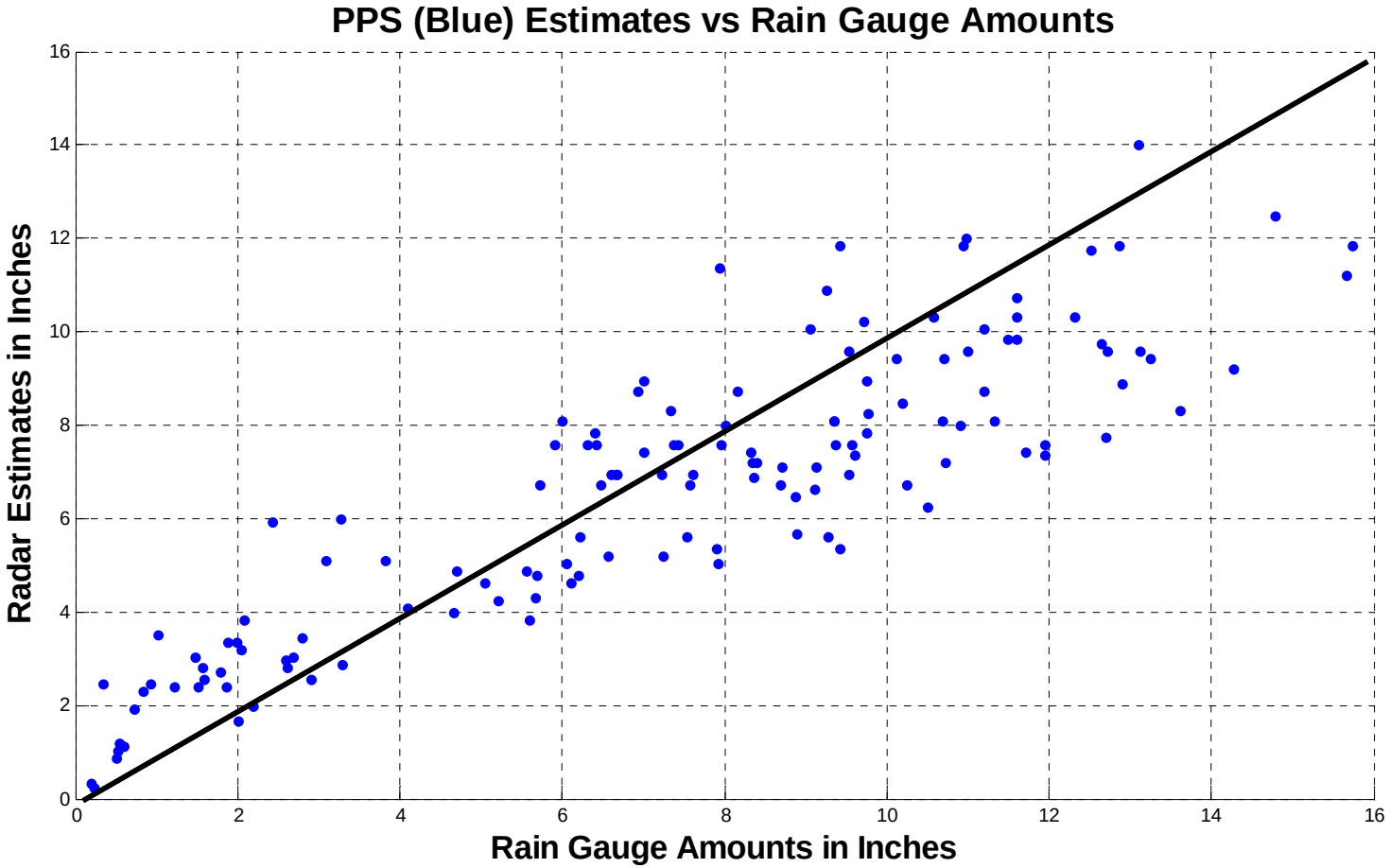
SUMMARY

- **KOUN/KVNX/KMHX DP QPE RMSE errors are lower than legacy PPS**
  - **DP QPE showed slightly higher bias for rainfall totals <= 1”**
- **For KICT DP QPE & PPS RMSE errors similar; primary source for errors appears to be for rain totals <= 1” at distances > 150 km**
  - **Issue appears to be related to ML challenges**
  - **Similar, but lower magnitude error trends for KOUN, KVNX and KMHX**
  - **WFOs have reported a similar error trend for KPBZ and KCLE**
- **DP QPE Verification/Improvement work will continue to be conducted via a joint partnership between the ROC, OS&T and NSSL**

BACKUP

KMHX IRENE RESULTS:

Category	Observations	RMSE		Statistical Significance
All Gauges:	R/G = 137,	PPS RMSE = 2.05”	DP RMSE = 1.82”	YES
Gauges > 5.0”:	R/G = 100,	PPS RMSE = 2.26”	DP RMSE = 2.00”	YES
Gauges > 8.0”:	R/G = 64,	PPS RMSE = 2.61”	DP RMSE = 2.05”	YES



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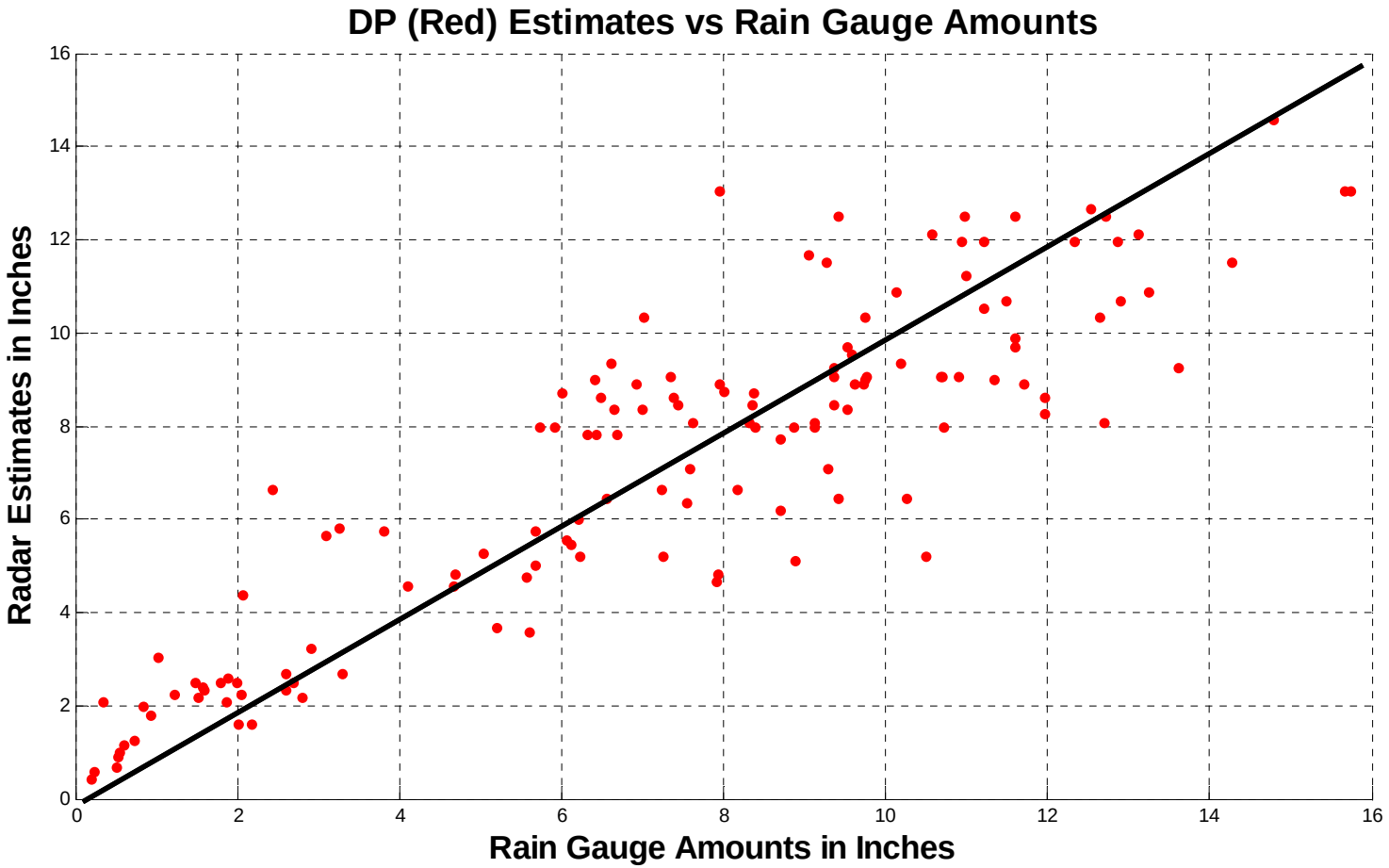

KMHX RESULTS:

Category	Observations	Bias Errors		Statistical Significance
All Gauges:	R/G = 137,	PPS Bias = -0.71”	DP Bias = 0.12”	YES
Gauges > 5.0”:	R/G = 100,	PPS Bias = -1.30”	DP Bias = 0.44”	YES
Gauges > 8.0”:	R/G = 64,	PPS Bias = -1.96”	DP Bias = 0.99”	YES

KOUN EXAMPLE: REDUCED HAIL CONTAMINATION

- Noted in warm season examples of DP QPE performing better than PPS
- Reason is related to hail contamination
- Data from Walters, OK rain gauge on 22-23 April 2011