WSR-88D Radar QPE for the HMT-west: Methodology, Results, and Future Plans

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Objective

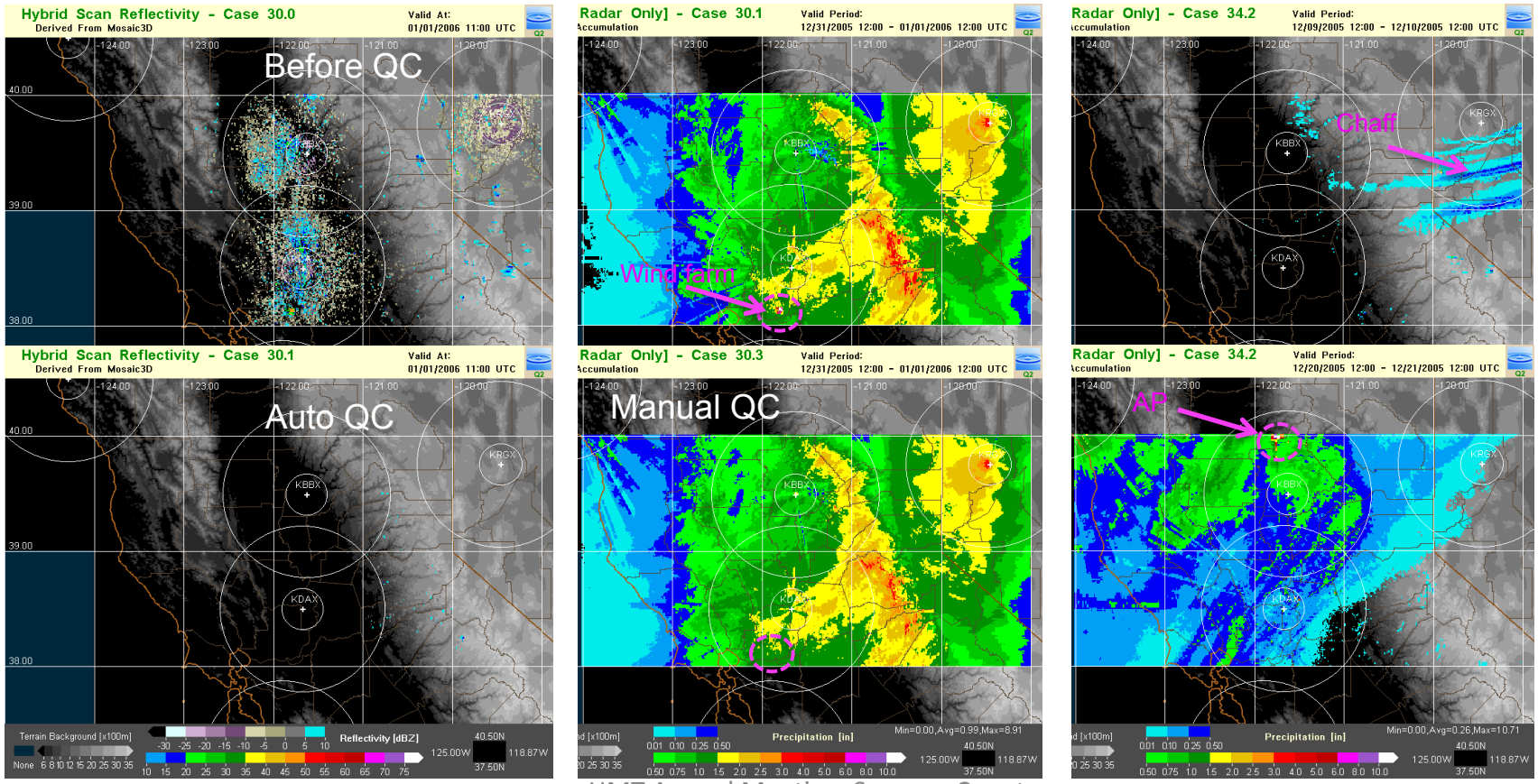
- Develop a methodology for the generation of high quality, radar-based quantitative precipitation estimation (QPE) products over the North Fork American River Basin (NFARB).
- The tool employed for generating radar-QPE products is **Q2**, a multi-sensor QPE analysis framework developed by NSSL.
- QPE generated on a 1-km grid and updated at 5 minute increments.

Methodology - Summary

- Single radar process
  - Reflectivity QC: to remove non-precipitation echoes
  - VPR (*vertical profile of reflectivity*) correction: to increase QPE accuracy by correcting errors from 1) bright band (overestimation) and 2) radar beam overshooting the melting layer (underestimation)
  - Constructing the hybrid scan reflectivity: to minimize blockage discontinuities
- Mosaicing
  - Mosaicing hybrid scan reflectivity fields from 4 radars onto a regional grid
- Precipitation estimation
  - Applying adaptive Z-R relationships to three regions (Coastal, Central Valley, and Sierra) to obtain instantaneous rates (every 5-min)
  - Aggregating into to 1, 3, 6, …24-hr accumulations.

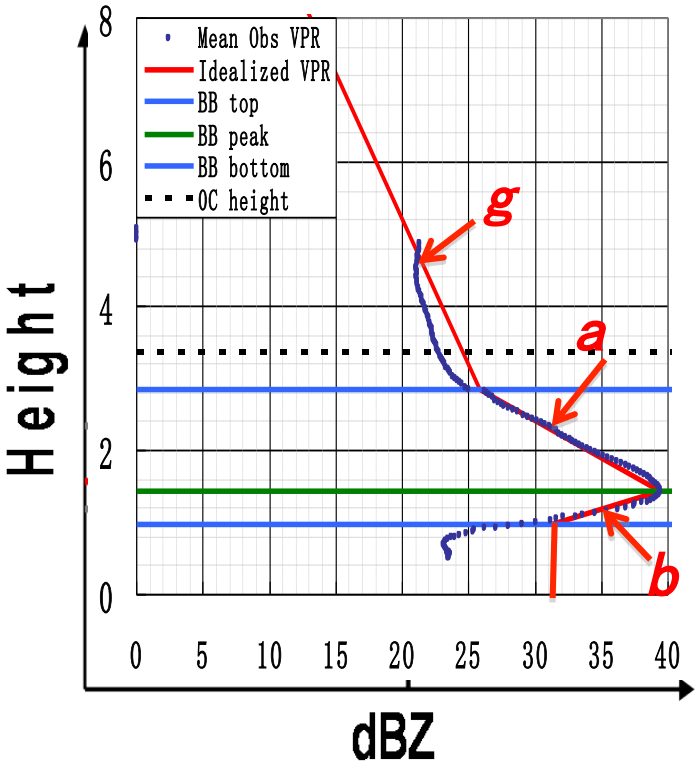
Methodology - Reflectivity QC

- Automated QC (clear air, ground clutter, some APs)
- Manual QC (wind farms)
- <u>Remaining challenges</u>: chaff, some APs



Methodology - Derive Vertical Profile of Reflectivity (VPR)

- Compute mean apparent VPR from base reflectivities
  - One VPR for each tilt
  - Compute (360°) azimuthal mean reflectivity at each range (every 1 km, from 10-300 km) using data that meets the following criteria:
    - VIL < 6.5kg/m^2 (stratiform)
    - Blockage <50%
    - REFL>15dBZ and CREF>30dBZ in bright band (BB) region (to capture BB peak);
    - REFL>0dBZ or CREF>30dBZ in ice region.
  - Derive idealized VPR by fitting the mean observed VPR with a linear model (see figure on the right)



VPR Parameters:

h_{0C}: freezing level height;

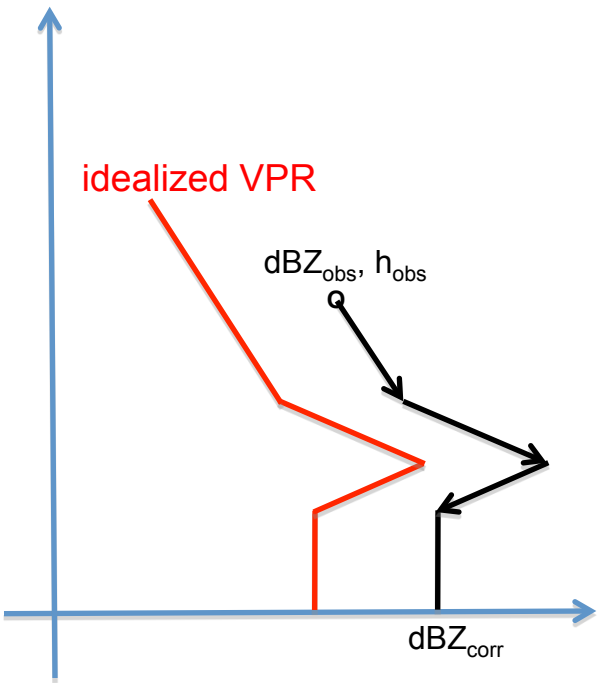
BB_{top}: height of BB top;

BB_{bot}: height of BB bottom;

a, b, g: slopes of the idealized VPR;

Methodology - VPR correction

- Apply the VPR correction to each tilt
  - Correction is applied only to reflectivity bins that meet the following criteria:
    - Height is above the BB bottom
    - VIL < 6.5kg/m^2
    - REFL>20dBZ in BB region
    - REFL>0dBZ or CREF>30dBZ in ice region
  - Adjustment is made to reflectivity (dBZ) according to the ideal VPR (see right figure)
    - *Assuming horizontally invariant vertical reflectivity structure*
    - *Assuming no change below BB bottom*



VPR correction parameters:

dBZ_{obs}: observed reflectivity;

h_{obs}: height of the reflectivity bin;

dBZ_{corr}: VPR corrected reflectivity;

Methodology - Hybrid Scan Reflectivity

- Derive hybrid scan reflectivity (HSR)
  - Traditional terrain-based hybrid scan
    - Consists of the lowest bins that have <50% blockage and bottom of the bins clear the ground by at least 50m.
  - Correction for partial blockages: Z' (mm^6/m^3) = Z/(1-***d***);
  - Seamless hybrid scan reflectivity (SHSR)
    - A weighted mean of the terrain-based hybrid scan and the next tilt above:

$$Z_{HSR} = \sum_{k=hst,hst+1} w_k Z_k \Big/ \sum_{k=hst,hst+1} w_k ; \qquad w = \left(1 - \frac{\delta}{0.5}\right) \cdot \left(\exp\left[-\frac{h - h_{0C}}{H}\right]\right)$$

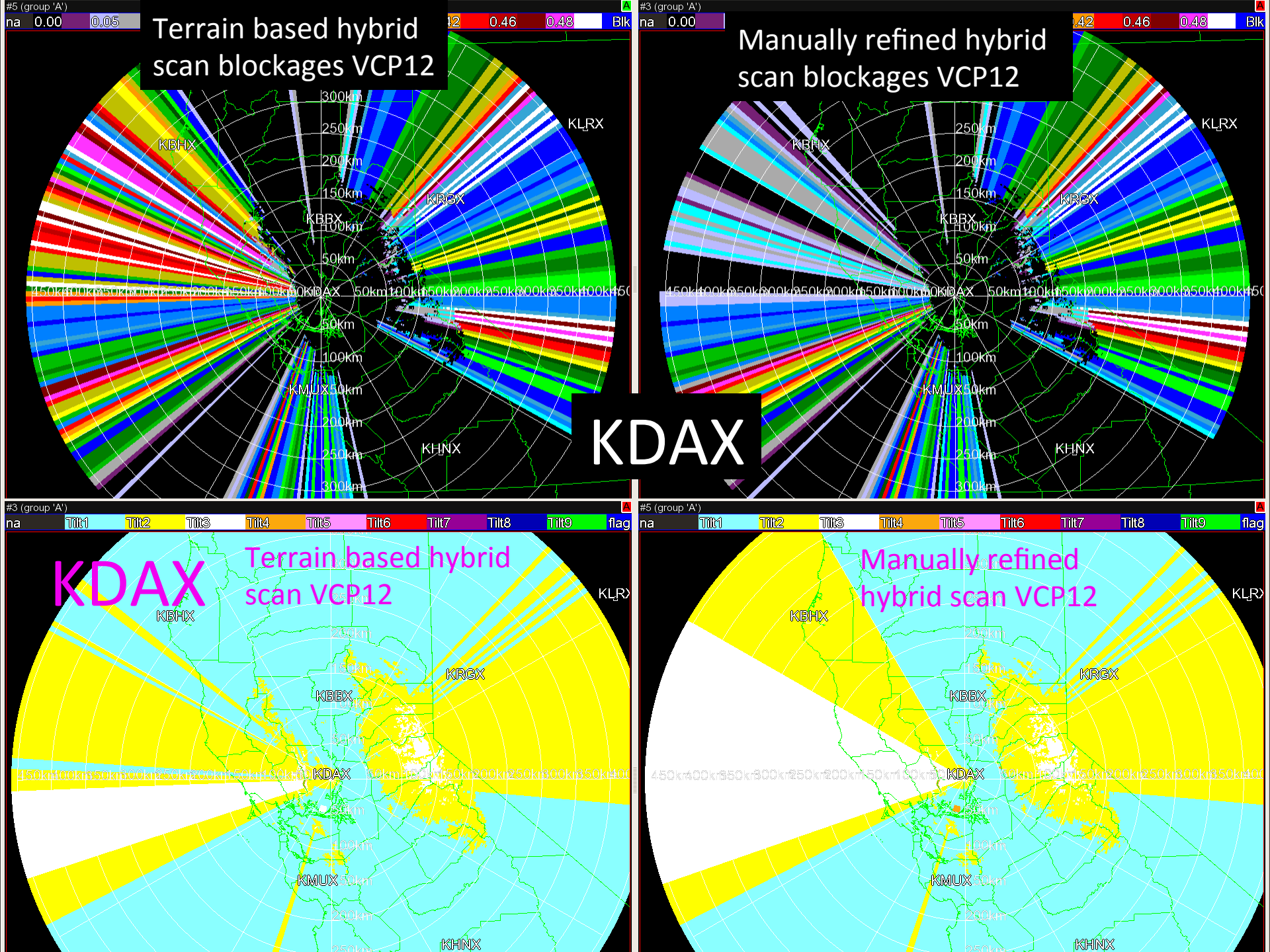
$$RQI = \sum_{k=hst,hst+1} w_k \Big/ 2;$$

Z_{HSR}: hybrid scan reflectivity (in mm^6m^{-3}); ***RQI***: Radar QPE Quality Index

Z_k: VPR corrected reflectivity on the ***k^{th}*** tilt; ***hst***: hybrid scan tilt number;

d: the amount of power blockage (dimensionless; ***d***=0.5 for 50%blockage);

h: beam height; ***h_{0C}***: freezing level height; ***H***: a height scale factor (default =1.5km).


Terrain based hybrid scan blockages VCP12
Manually refined hybrid scan blockages VCP12
KDAX
KLRX
KBHX
KRGX
KBBX
KMUX
KHNX
Terrain based hybrid scan VCP12
Manually refined hybrid scan VCP12
Tilt1
Tilt2
Tilt3
Tilt4
Tilt5
Tilt6
Tilt7
Tilt8
Tilt9
flag

Methodology - Hybrid Scan Reflectivity Mosaic

- Single radar, seamless hybrid scan reflectivity fields are mosaiced using a weighted mean:

$$Z_{HSR}^{mos} = \frac{\sum_i w_L^{\,i} \bullet w_H^{\,i} \bullet Z_{HSR}^{\,i}}{\sum_i w_L^{\,i} \bullet w_H^{\,i}}; \qquad RQI^{mos} = \frac{\sum_i w_L^{\,i} \bullet w_H^{\,i} \bullet RQI^{i}}{\sum_i w_L^{\,i} \bullet w_H^{\,i}}$$

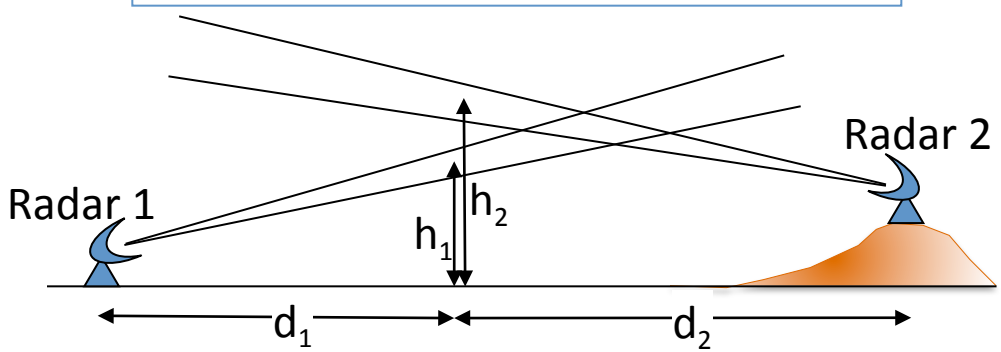
Z_{HSR}^{mos} : mosaiced hybrid scan reflectivity;

RQI^{mos} : mosaiced radar QPE quality index;

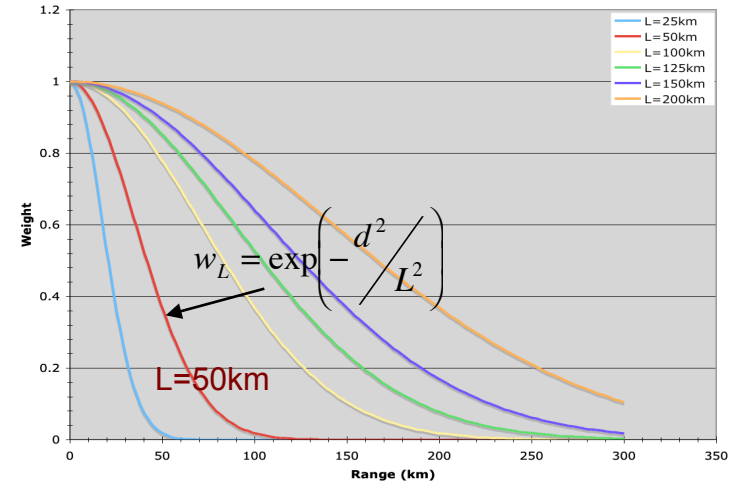
Z_{HSR}^{i} : HSR from the ***i^th*** radar;

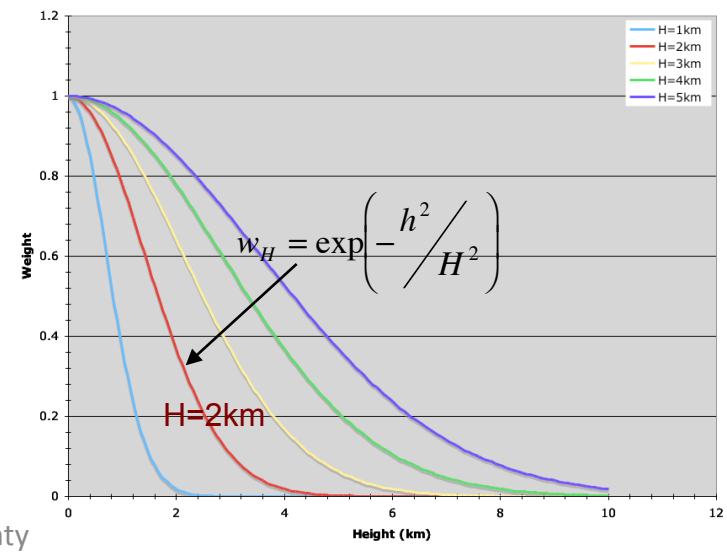
w_L, w_H: weights given to the HSR from the ith radar

d: range from radar; *h*: height AGL.



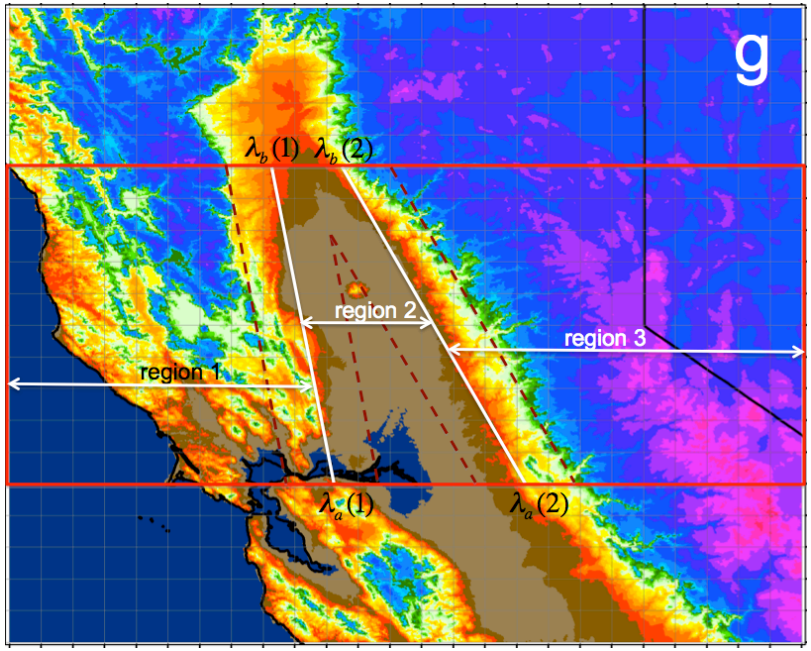
d: range; h: height

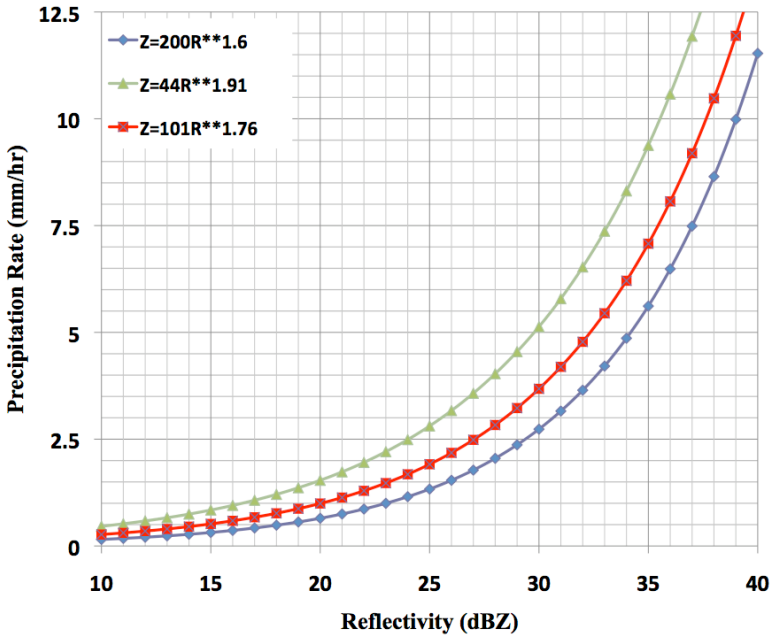




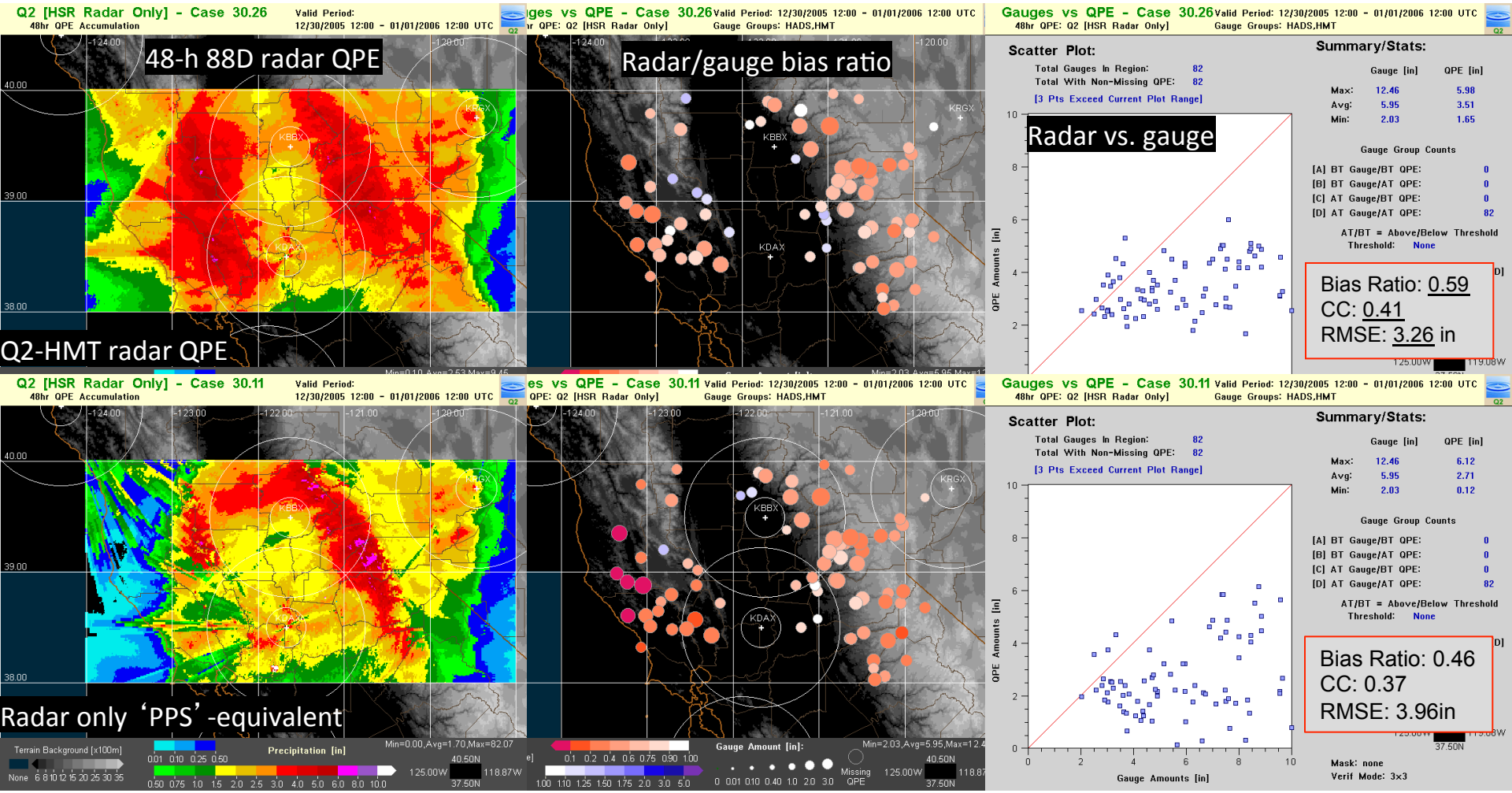
Methodology - Adaptive Z-R relationship

- An adaptive Z-R approach is used for different zones
  - Coastal: $Z = 44R^{1.91}$ (Martner et al. 2008)
  - Central Valley: $Z = 200R^{1.6}$ (Marshall-Palmer)
  - Sierra: $Z = 101R^{1.76}$ (Matrosov et al. 2007)

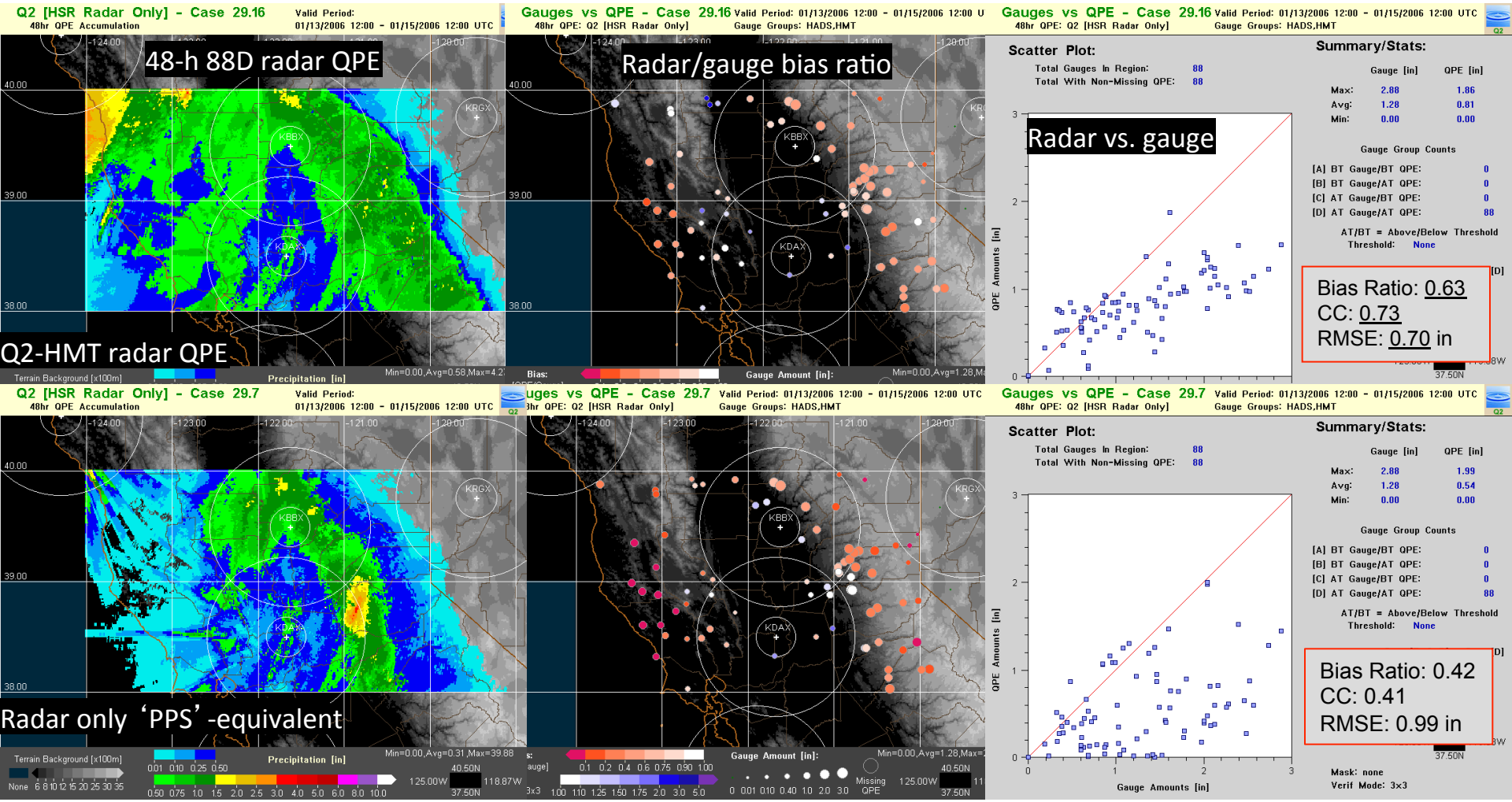




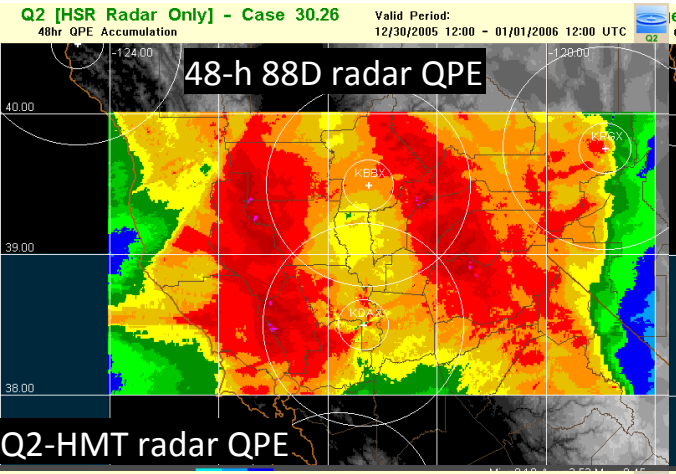
Results: IOP4, Q2-HMT vs. Radar Only ‘PPS’

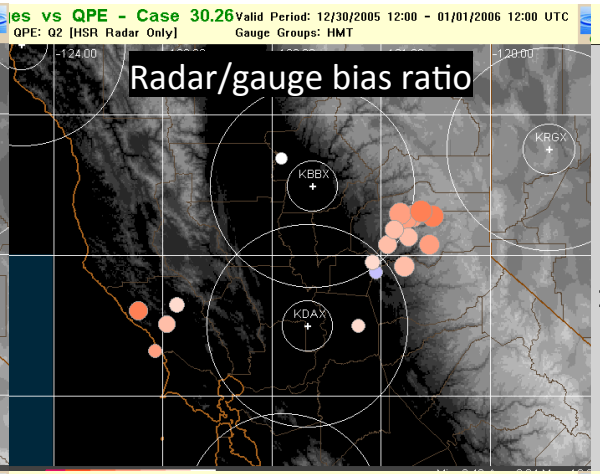


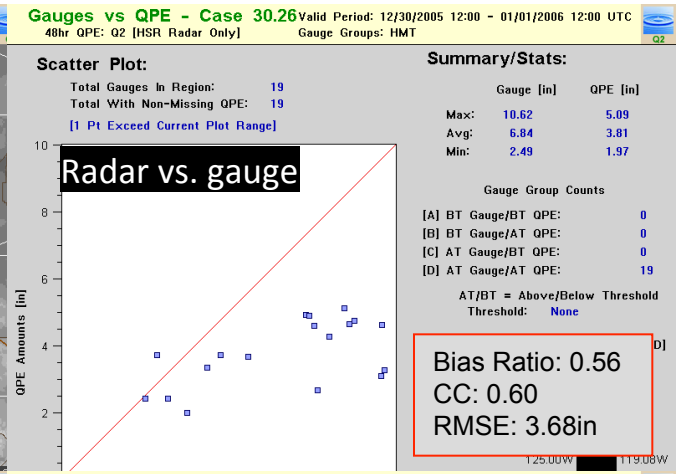
Results: IOP7, Q2-HMT vs. Radar Only ‘PPS’

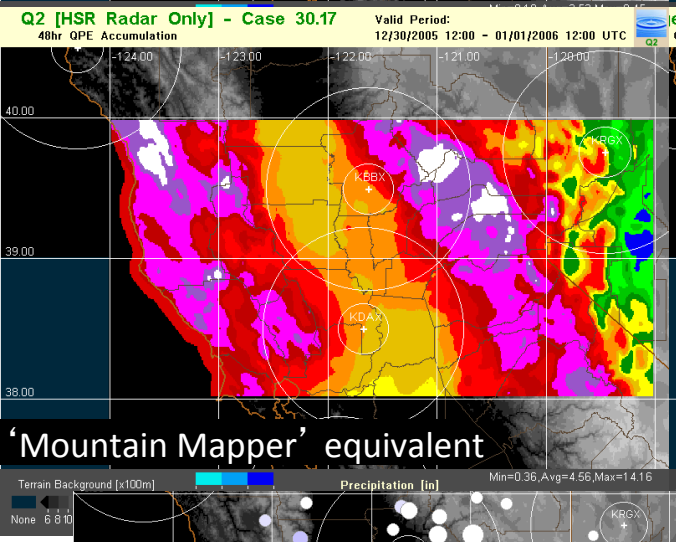


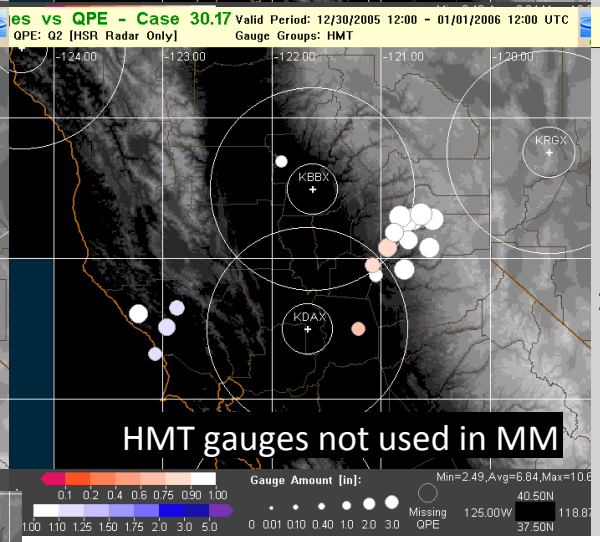
Results: IOP4, Q2-HMT vs. ‘Mountain Mapper’

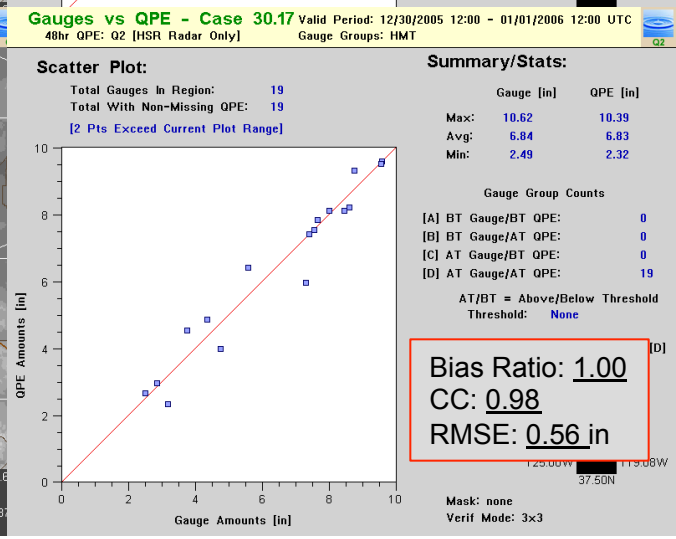


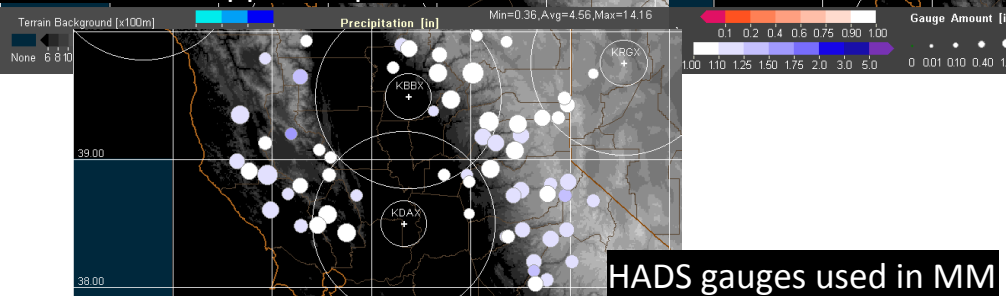




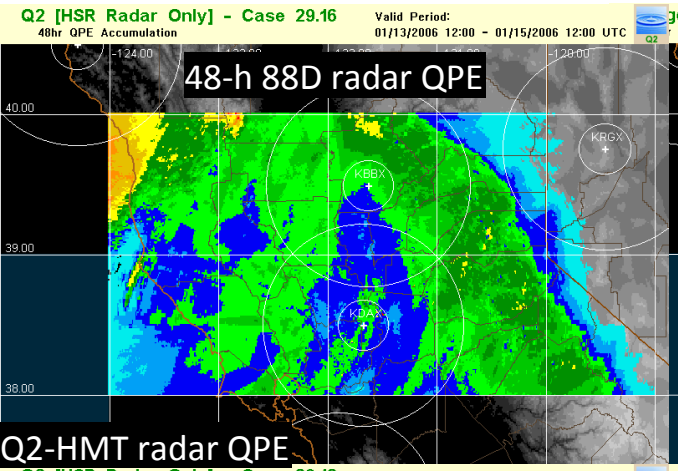


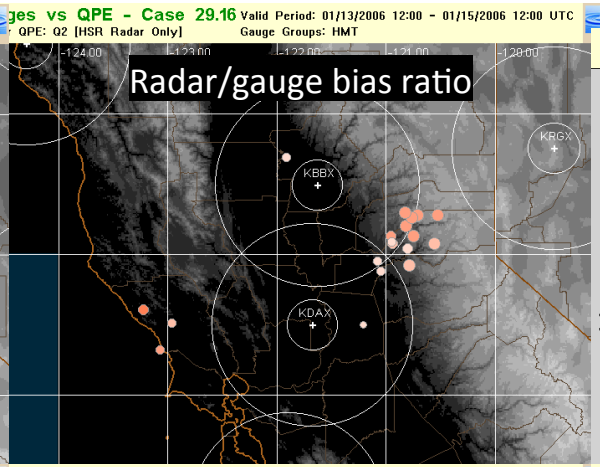


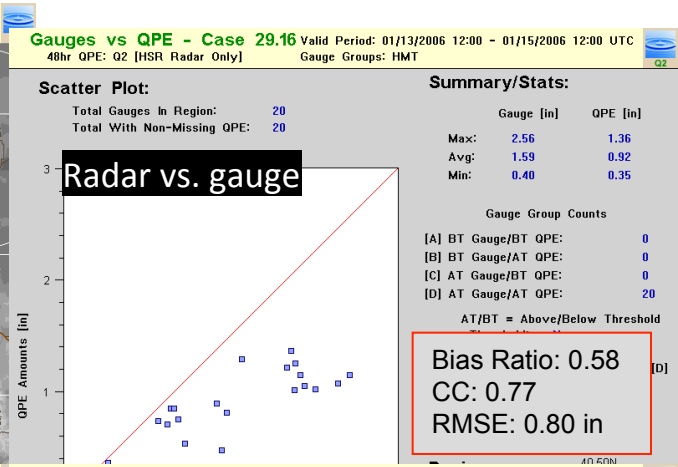


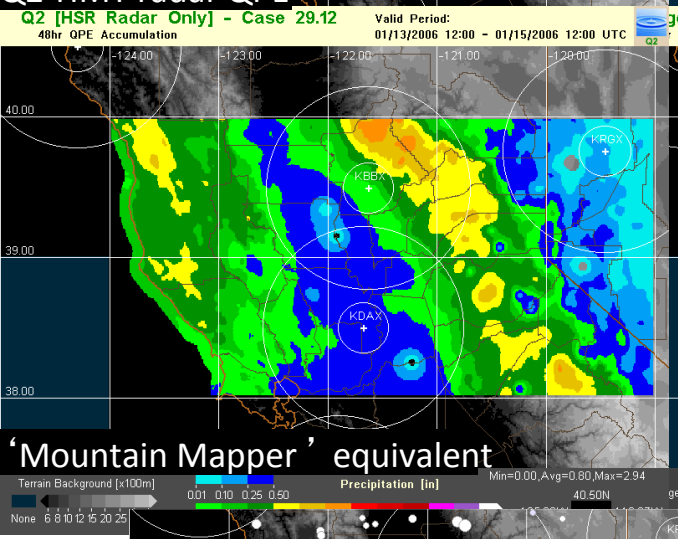


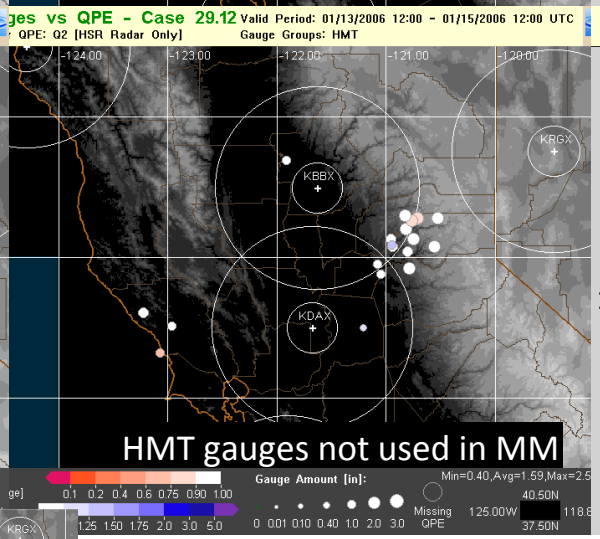
Results: IOP7, Q2-HMT vs. ‘Mountain Mapper’

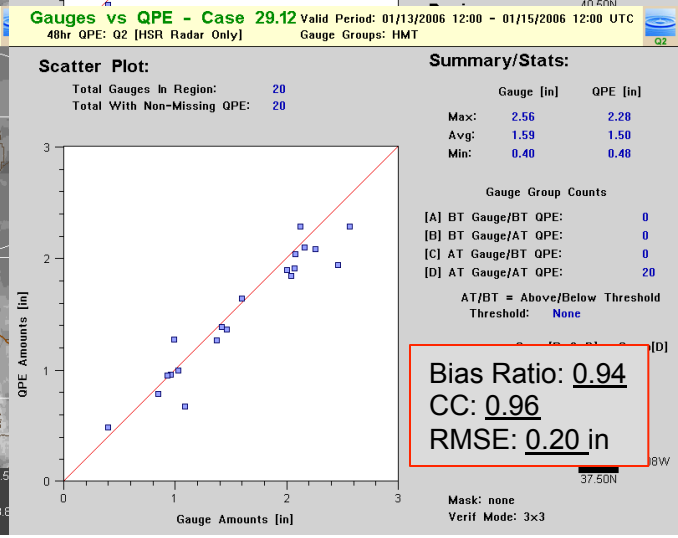








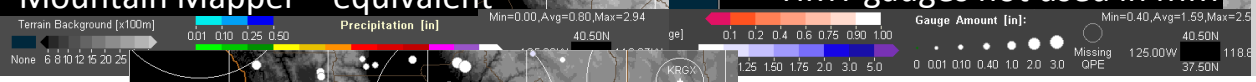


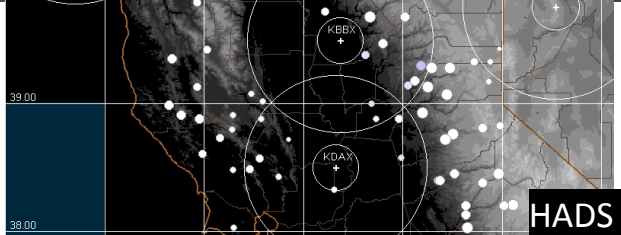


Q2-HMT radar QPE

‘Mountain Mapper’ equivalent

HMT gauges not used in MM

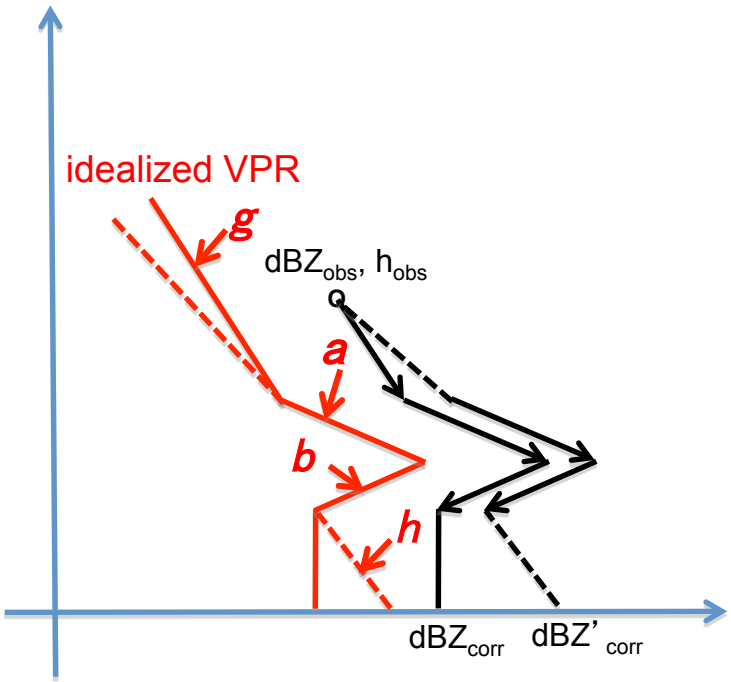


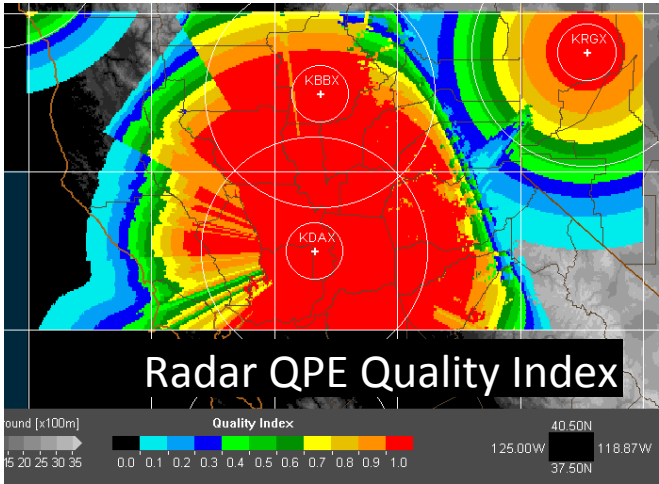


HADS gauges used in MM

VPR correction benefits/challenges

- Benefits:
  - Reduce radar vs. gauge scatter
  - Reduce overestimation associated with BB
  - Reduce underestimation where radar sampling in ice region
- Challenges…
  - Orographic enhancement result in non-zero slope (h) below BB bottom
  - Inaccurate VPR slope (g) above BB top due to poor beam resolution and averaging VPR over large area
  - No correction can be made when melting layer is at or lower than radar height
  - Both contribute to underestimation (dBZ_{corr} too small)

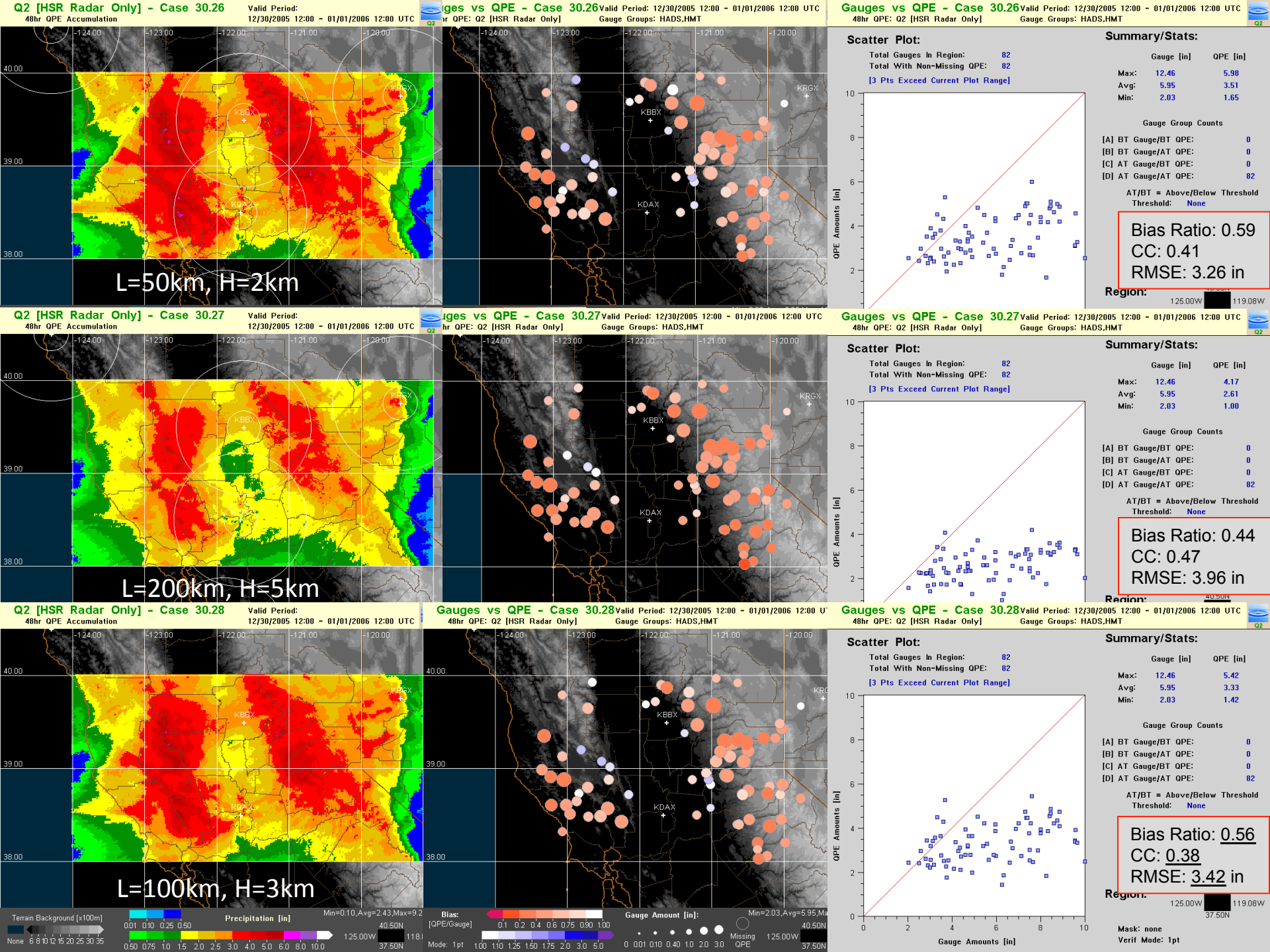




Summary & Future Work

- Significant challenges exist for creating an accurate radar-based QPE in the western United States
- Used Q2 framework to assess various multi-sensor techniques and approaches for the development of the HMT – Methodology
- Radar QPE reanalysis for HMT 2005-2006 field season is ongoing using the presented methodology
- HMT-west 2010-2011
  - Running the HMT-Methodology QPE in real-time (if resources allow)

Refinement of the HMT-Methodology will continue


Q2 [HSR Radar Only] - Case 30.26
48hr QPE Accumulation
Valid Period:
12/30/2005 12:00 - 01/01/2006 12:00 UTC
Gauges vs QPE - Case 30.26
Valid Period: 12/30/2005 12:00 - 01/01/2006 12:00 UTC
48hr QPE: Q2 [HSR Radar Only]
Gauge Groups: HADS,HMT
L=50km, H=2km
Scatter Plot:
Total Gauges In Region: 82
Total With Non-Missing QPE: 82
[3 Pts Exceed Current Plot Range]
Summary/Stats:
Gauge [in] QPE [in]
Max: 12.46 5.98
Avg: 5.95 3.51
Min: 2.03 1.65
Gauge Group Counts
[A] BT Gauge/BT QPE: 0
[B] BT Gauge/AT QPE: 0
[C] AT Gauge/BT QPE: 0
[D] AT Gauge/AT QPE: 82
AT/BT = Above/Below Threshold
Threshold: None
Bias Ratio: 0.59
CC: 0.41
RMSE: 3.26 in
Region:
125.00W 119.08W
37.50N
QPE Amounts [in]
Gauge Amounts [in]
Q2 [HSR Radar Only] - Case 30.27
48hr QPE Accumulation
Valid Period:
12/30/2005 12:00 - 01/01/2006 12:00 UTC
Gauges vs QPE - Case 30.27
Valid Period: 12/30/2005 12:00 - 01/01/2006 12:00 UTC
48hr QPE: Q2 [HSR Radar Only]
Gauge Groups: HADS,HMT
L=200km, H=5km
Scatter Plot:
Total Gauges In Region: 82
Total With Non-Missing QPE: 82
[3 Pts Exceed Current Plot Range]
Summary/Stats:
Gauge [in] QPE [in]
Max: 12.46 4.17
Avg: 5.95 2.61
Min: 2.03 1.00
Gauge Group Counts
[A] BT Gauge/BT QPE: 0
[B] BT Gauge/AT QPE: 0
[C] AT Gauge/BT QPE: 0
[D] AT Gauge/AT QPE: 82
AT/BT = Above/Below Threshold
Threshold: None
Bias Ratio: 0.44
CC: 0.47
RMSE: 3.96 in
Q2 [HSR Radar Only] - Case 30.28
48hr QPE Accumulation
Valid Period:
12/30/2005 12:00 - 01/01/2006 12:00 UTC
Gauges vs QPE - Case 30.28
Valid Period: 12/30/2005 12:00 - 01/01/2006 12:00 UTC
48hr QPE: Q2 [HSR Radar Only]
Gauge Groups: HADS,HMT
L=100km, H=3km
Scatter Plot:
Total Gauges In Region: 82
Total With Non-Missing QPE: 82
[3 Pts Exceed Current Plot Range]
Summary/Stats:
Gauge [in] QPE [in]
Max: 12.46 5.42
Avg: 5.95 3.33
Min: 2.03 1.42
Gauge Group Counts
[A] BT Gauge/BT QPE: 0
[B] BT Gauge/AT QPE: 0
[C] AT Gauge/BT QPE: 0
[D] AT Gauge/AT QPE: 82
AT/BT = Above/Below Threshold
Threshold: None
Bias Ratio: 0.56
CC: 0.38
RMSE: 3.42 in
Mask: none
Verif Mode: 1pt
Terrain Background [x100m]
Precipitation [in]
Bias: [QPE/Gauge]
Gauge Amount [in]:
Missing QPE