A Radar Rainfall Estimation Tool for Water Resource Management in California

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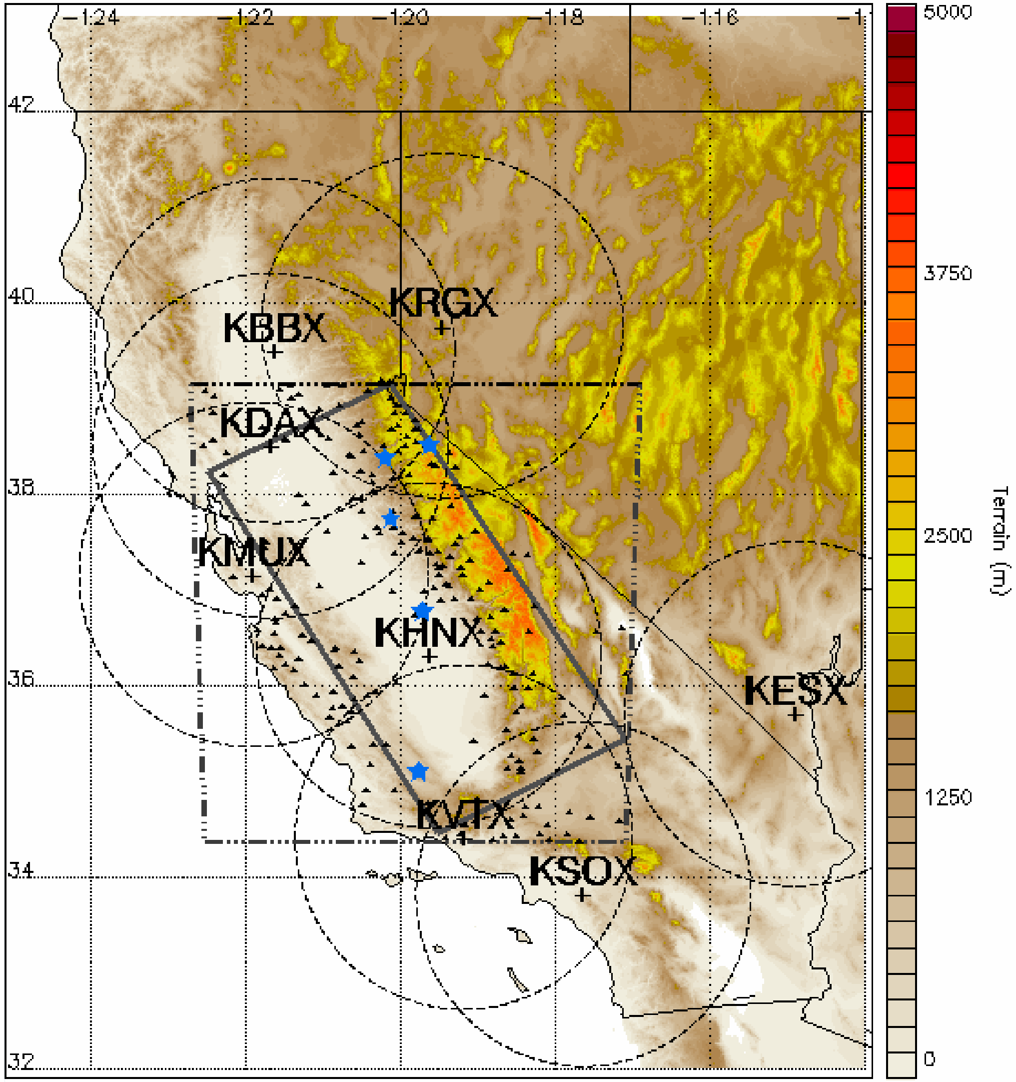
Motivation

- Water resource management in California's agriculturally dominated San Joaquin Valley is complex due to the limited sources and competitive needs
- NASA's Earth Science Program provided ARRA funds to improve water resource management in this region
- UAH was tasked with developing a radar-based tool to estimate precipitation over Central California during Nov 2010 – Mar 2011 for integration with a land surface hydrologic model

Radar and Rain Gauge Coverage



- Central California
- 220 rain gauges
- 8 WSR-88Ds

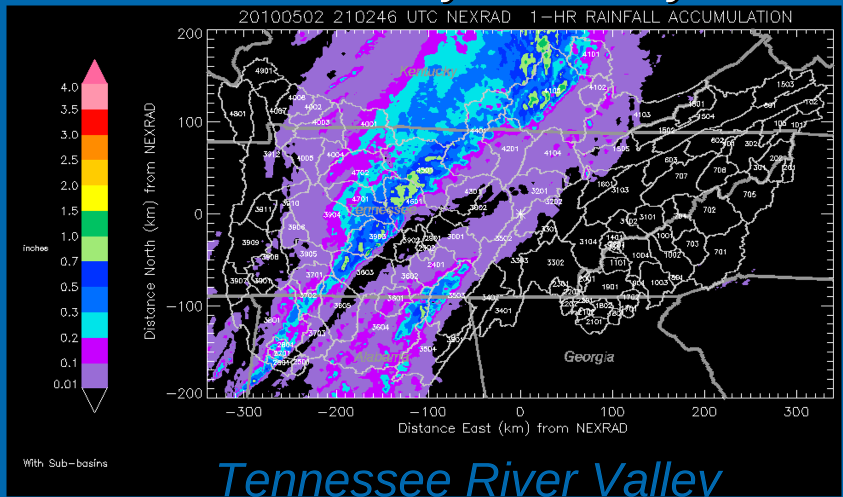
Key Issue:

- Widely varying, complex terrain (sea level to 4,421 m MSL)
  - Radar beam occultation
  - Variable *Z-R* relationships
  - NEXRAD not always measuring precipitation intensity near the surface, especially within the mountains

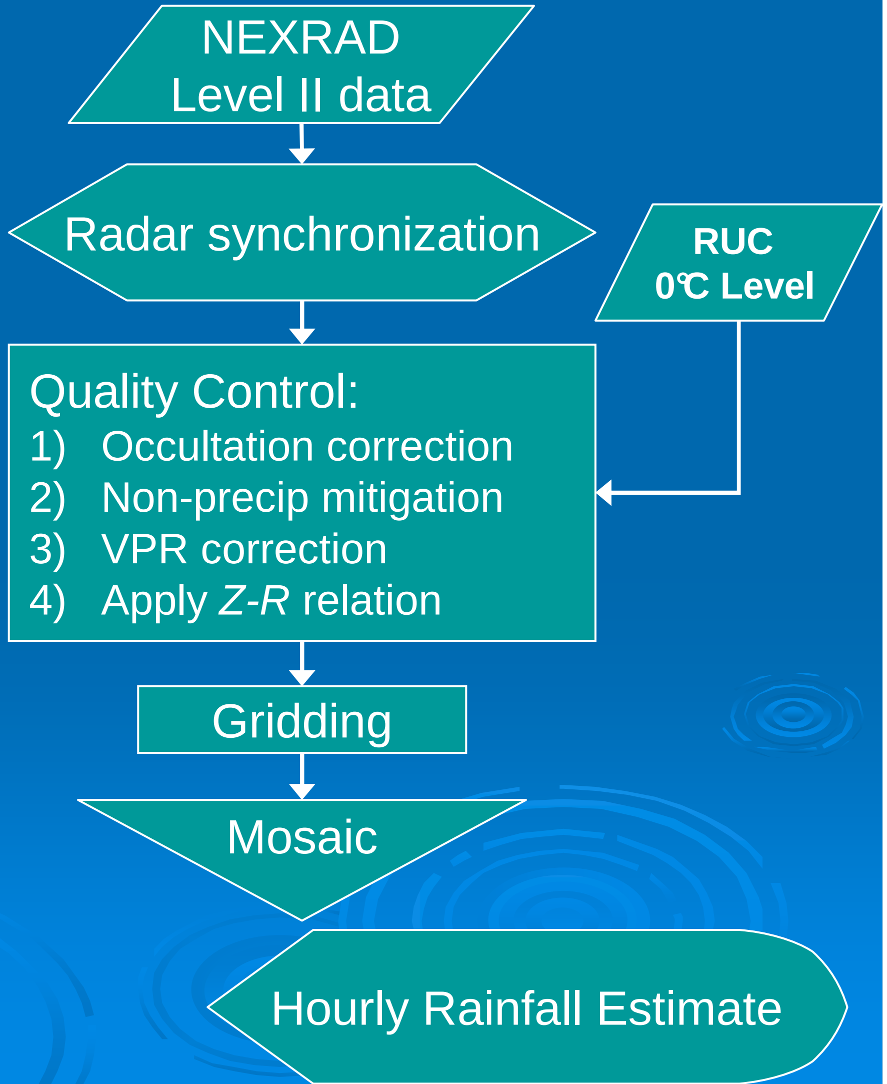
(e.g., Gourley et al. 2009)

NEXRAD Rainfall Estimation Processing System (NREPS)

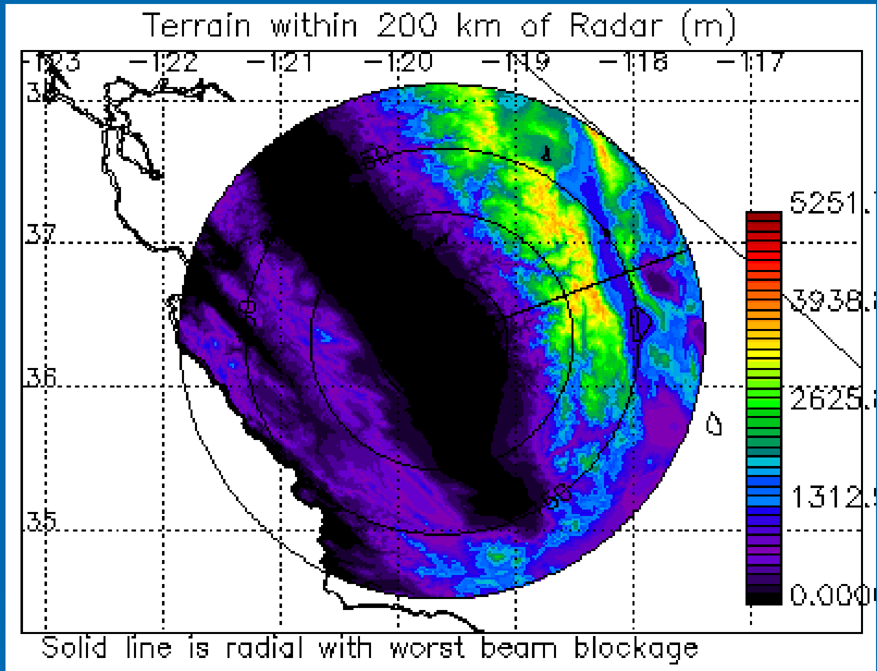
- Originally developed for the Tennessee Valley Authority

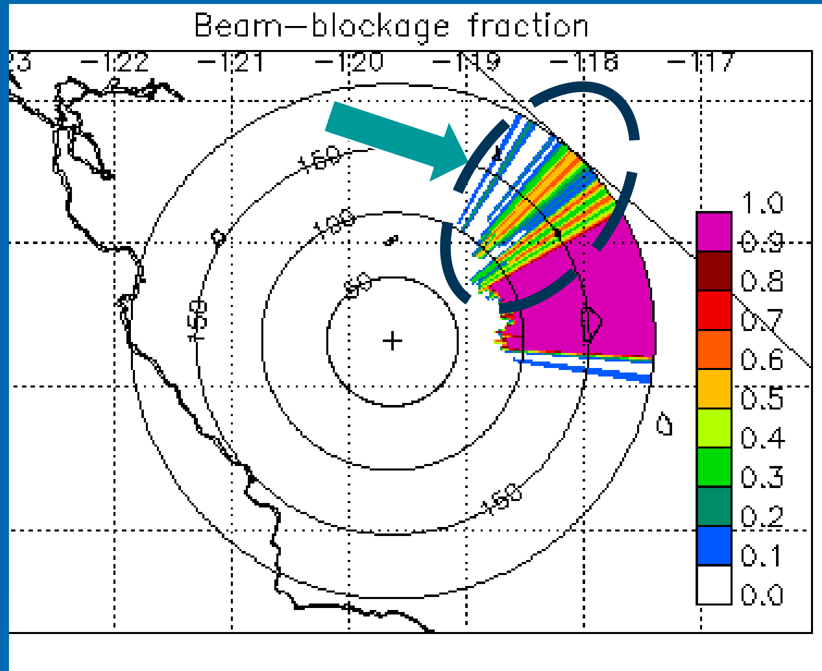


- NREPS ingests WSR-88D level II formatted data and synchronizes it
- Can operate in real-time mode using data from LDM or archive mode using data from NCDC
- Produces hourly rainfall estimates with a 2 km^2 resolution



Blockage Correction





- Terrain features can block the radar beam resulting in a lower estimation of rainfall across mountainous regions
- Using digital elevation models and a radar beam model, the radar reflectivity was adjusted to recover the portion that is blocked (Lang et al. 2009) for BBF < 90%

Mitigation of Non-precipitation

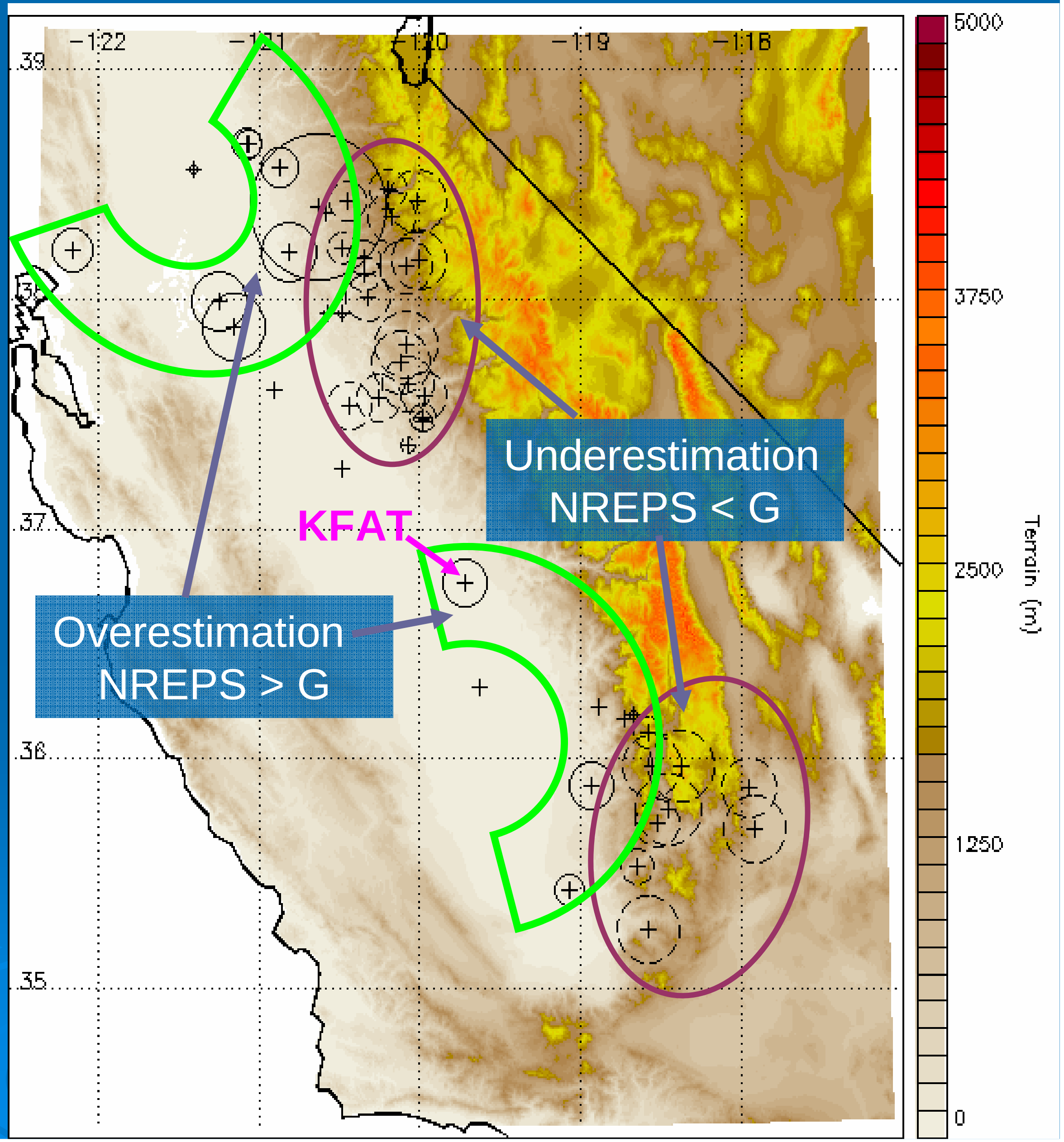
- Apply Data Quality Assurance algorithm developed by MIT/Lincoln Labs for NEXRAD ORPG Build 3 (Smalley et al. 2003):
  - Use notch width filter on Doppler velocity to remove some anomalous propagation
  - Remove sun strobes
- Check for precipitation and type:
  - $H_{0°C} \geq 1$ km AGL (RUC) + $VCP_{clear\text{-}air} \rightarrow$ no precip
  - $H_{0°C} < 1$ km AGL (RUC) + $VCP_{clear\text{-}air} \rightarrow$ snow
  - Otherwise rain
- Use the 3-D structure of the radar reflectivity volume to further mitigate non-precipitation echoes (Steiner and Smith 2002)

Calculating Rain Rate (*Z*-*R*)

- Examined several previous winter rainfall events in California using Marshall-Palmer *Z*-*R* ($Z = 200\ R^{1.4}$)
- M-P was biased 30% low relative to rain gauges and thus we adjusted the Z-R accordingly: $Z = \mathbf{131.5}\ R^{\mathbf{1.6}}$
- Turns out this is within the range of several other published *Z*-*R* relations derived from both radar and disdrometers in California (Kingsmill et al. 2006; Martner et al. 2008)

Geographical Distribution of Error

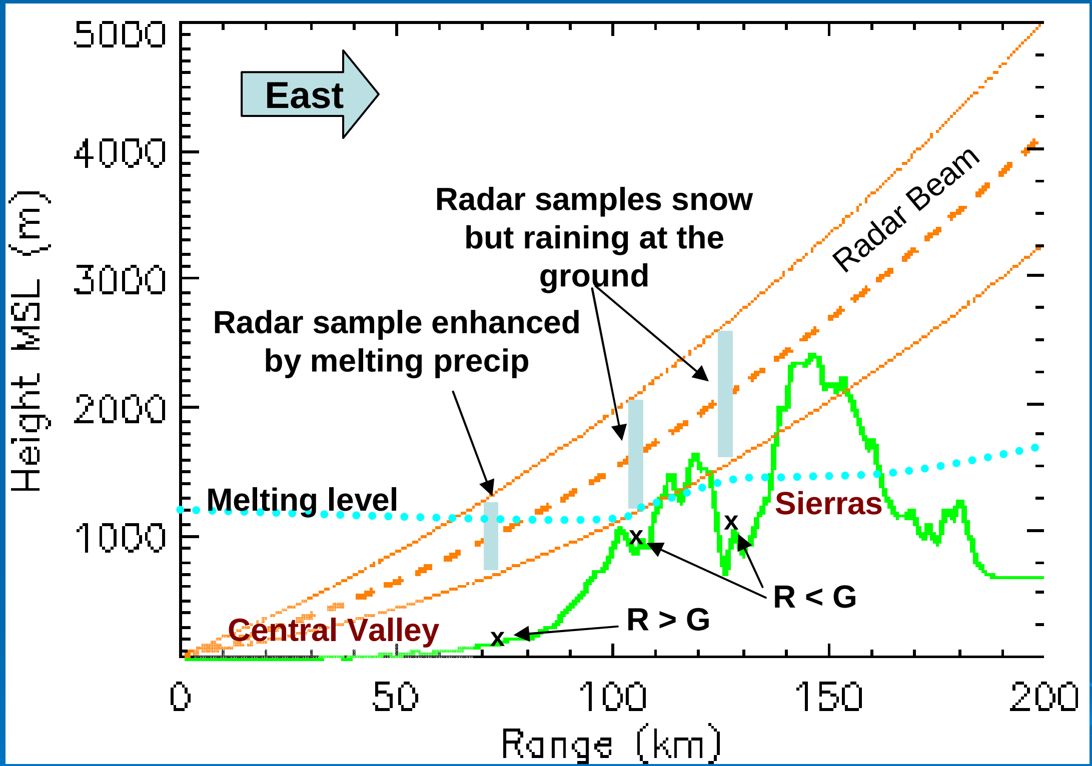
- NREPS < G in higher elevations and far from radars
  - terrain causes radar estimates of precip high above ground
  - radar sample height increases with distance from radar
- NREPS > G at distance of 50-75 km from radar
  - radar sampling of the melting layer
  - radar measurement is not at the ground



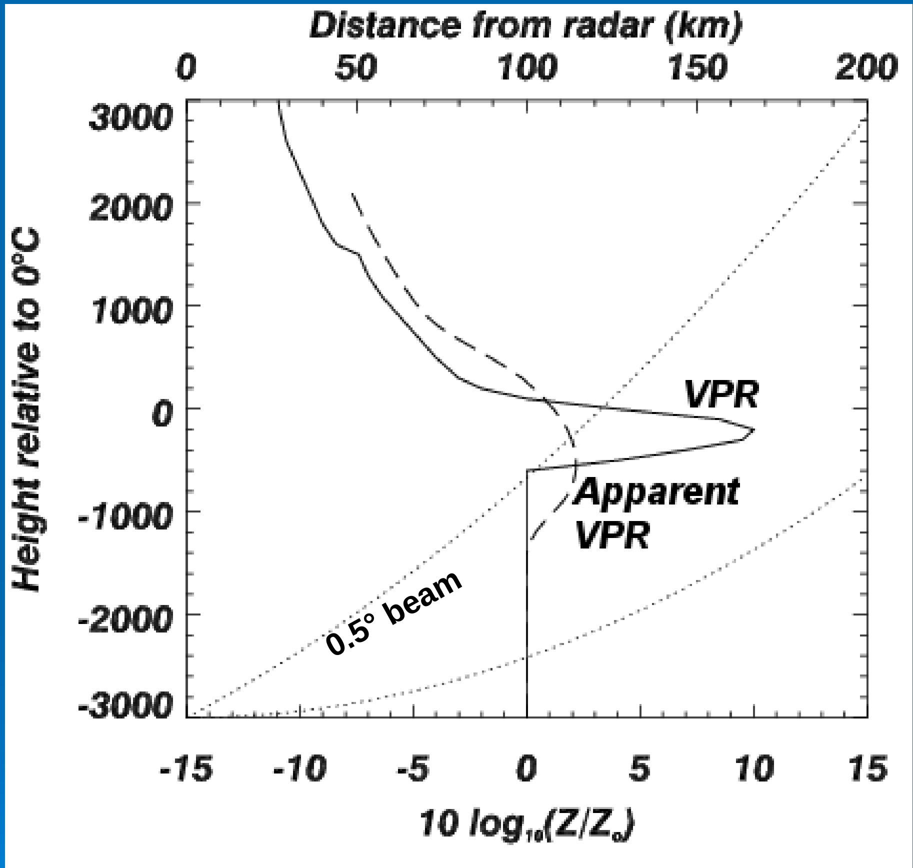
Vertical Profile of Reflectivity

- The characteristics of melting of snow cause an enhancement of radar reflectivity measured within the melting layer (i.e., radar bright band)
- Below the melting layer, reflectivity is for the most part constant and rainfall estimation is less complex
- However, the height of the radar sample increases away from the radar

→ So estimating the rainfall at the surface becomes more challenging further from the radar (where radar sample is within and above the melting layer)



Accounting for the Vertical Profile of Reflectivity (VPR)

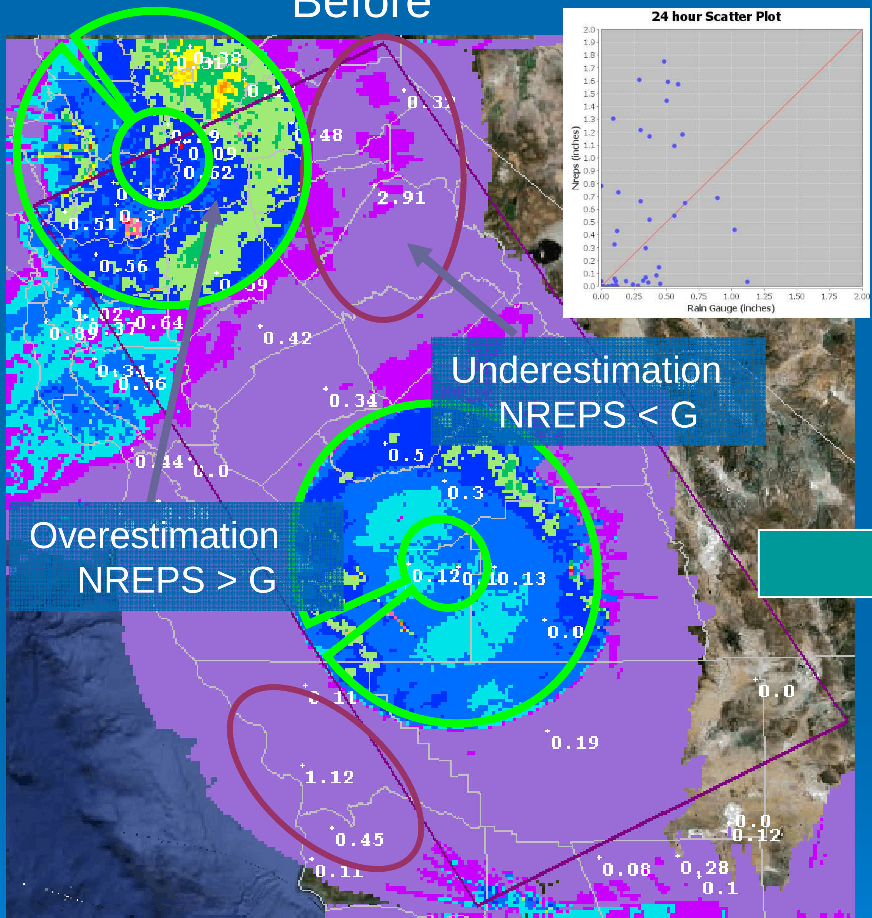


- VPR model taken from S-band profiler observations of BB rainfall in Central California during CALJET and PACJET (Neiman et al. 2005; Martner et al. 2008)
- Positioned VPR model relative to the RUC analysis melting level
- Adjusted VPR for beam broadening with range (i.e, Apparent VPR)
- Apparent VPR model was used to adjust the reflectivity calculated by the radar (Z) to it's value at the surface (Z_0)

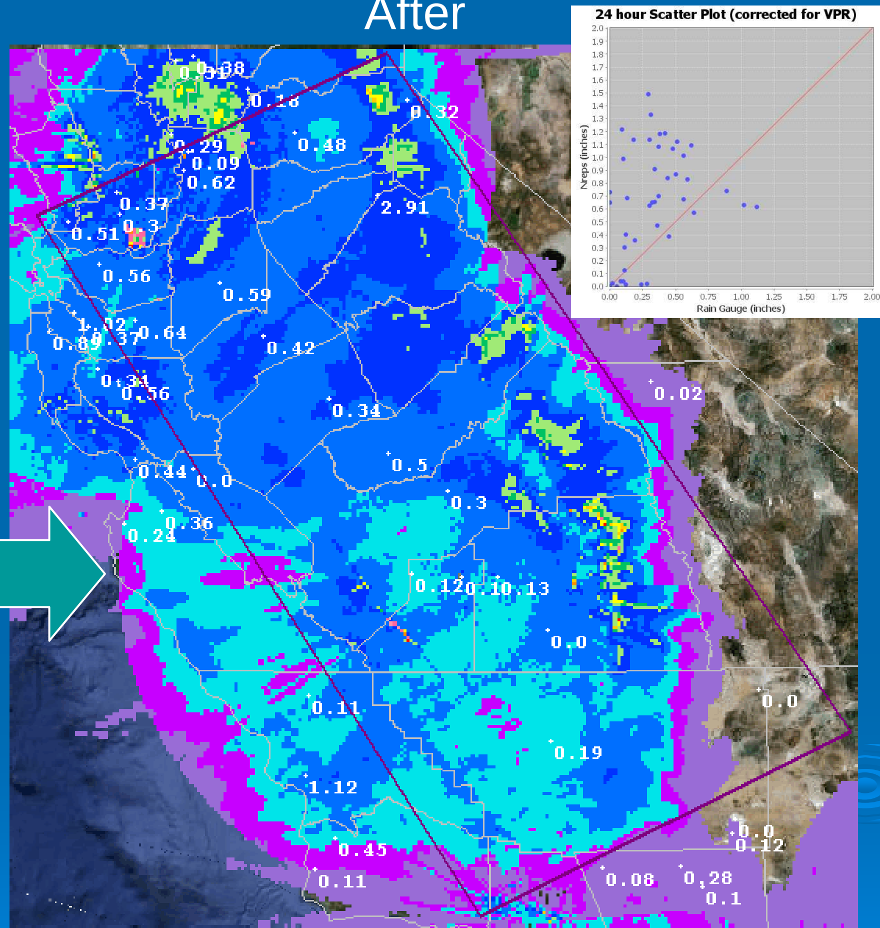
→ *Adjust radar measurements using VPR model to improve precipitation estimate* ***at the surface***

Effect of VPR Correction

Before



After

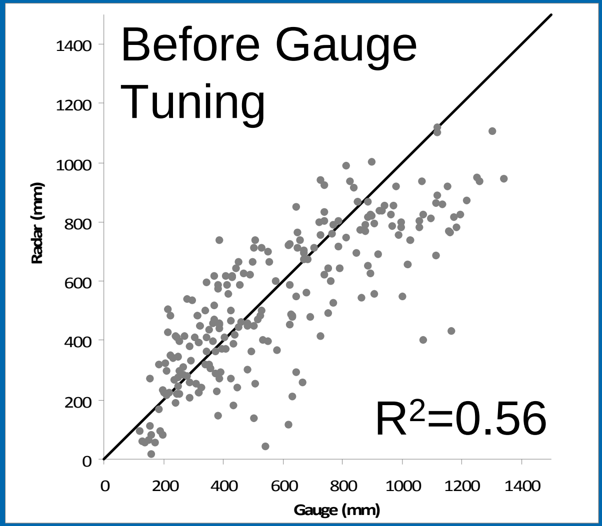


Ending Nov 22 at 00 UTC

- →Reduced low bias in mountains
- →Reduced high bias at 50-75 km from radars

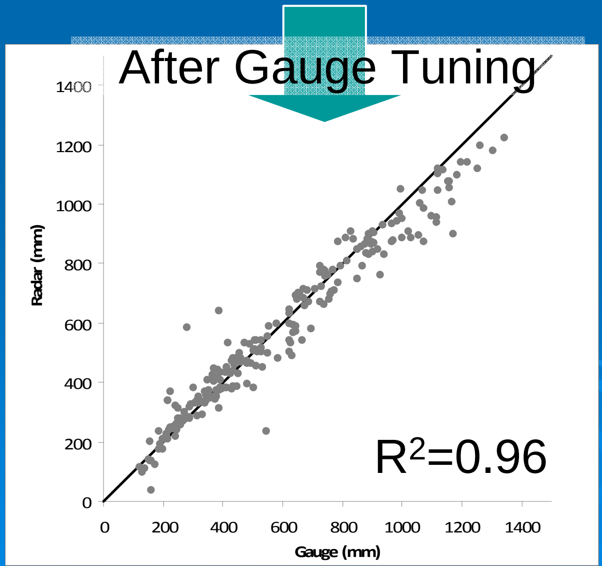
Utilizing Rain Gauges

- Less than 10% overall relative bias in NREPS estimates (183 rain gauges)
- However, regional bias was present
  - R-G > 0 in San Joaquin Valley
  - R-G < 0 in mountains
  - Attributed to unique VPR model and *Z-R* relation applied to entire domain

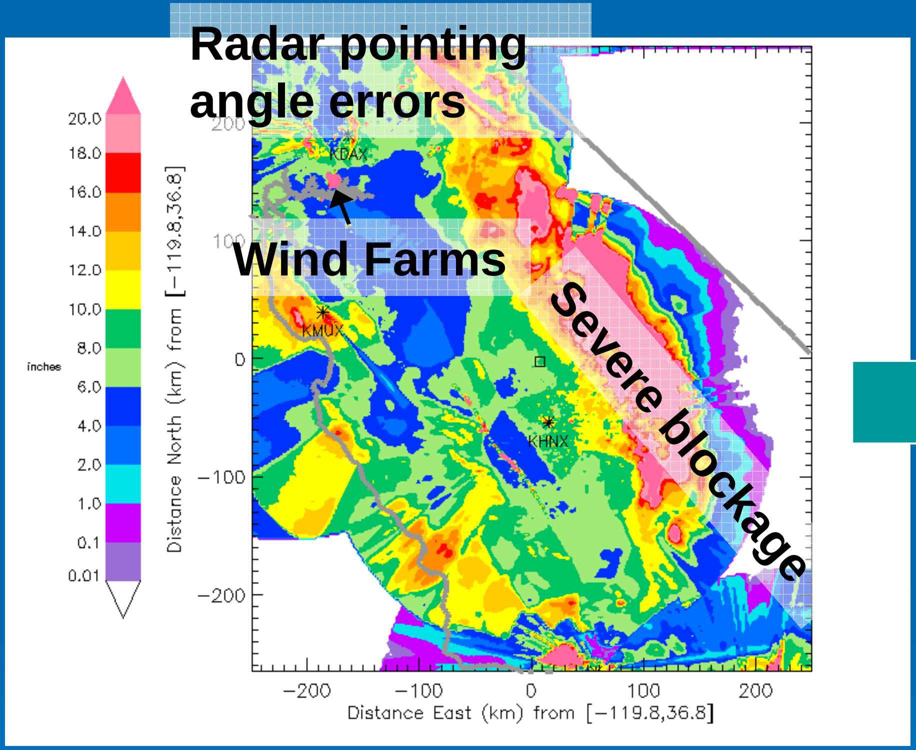


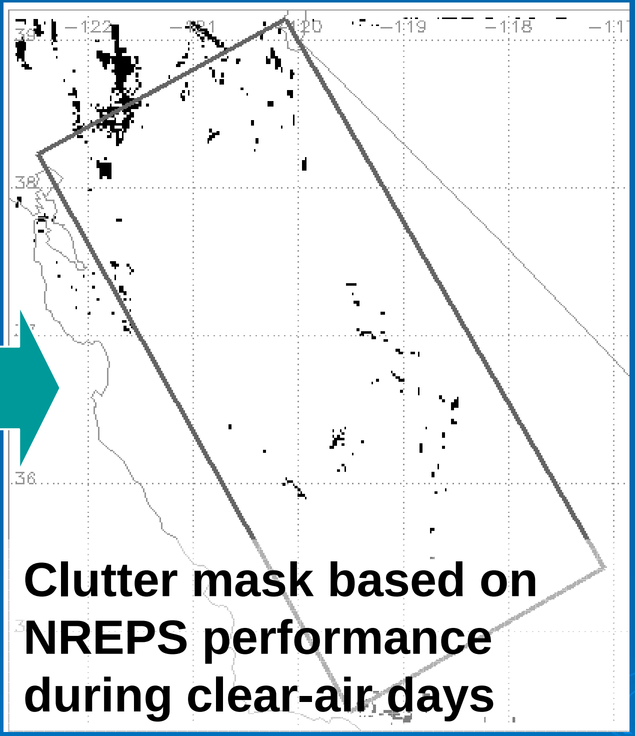
<u>Solution</u>: → Apply local gauge tuning:
(e.g., Wilson and Brandes 1979, Anagnostou et al. 1998)

- Calculated monthly bias of NREPS estimate at each rain gauge
- Produced a gridded local bias map with 20 km radius of influence
- Applied local bias grid to each hourly NREPS estimate



Limitations





- Issues still remain as seen in the Dec-Jan 2010/2011 rainfall map above
- Developed a clutter mask based upon identified clear air days between Nov-March showing where NREPS produced false rainfall each day
- This climatologically-based clutter mask can then be applied to the NREPS hourly grids before ingesting rainfall estimates into hydrologic model

Future Work

- Utilize wealth of additional info provided by dual-polarimetric NEXRADs
  - Precipitation type and amount
  - Melting level identification
- Employ an adaptable VPR (e.g., Zhang et al. 2009)
- Use NASA satellites to improve estimates
  - TRMM PR to validate and improve the VPR model
  - Identify clouds/precip and provide better clutter filtering
- Near real-time gauge tuning