HMT QUANTITATIVE PRECIPITATION ESTIMATION ACTIVITIES

FY12 ACCOMPLISHMENTS AND FY13 PLANS

Rob Cifelli ESRL
Ken Howard NSSL

OULTINE

- HMT-QPE objectives
- FY12 activities
  - Overview of results
  - R2O activities
  - Challenges
- FY13 plans
  - Activities
  - Challenges
  - R2O plans

HMT-QPE OBJECTIVES

- QPE Vision
  - Advance the state-of-the-art science for quantitative precipitation estimation
- QPE Mission
  - Working with partners across NOAA, establish a center of excellence to evaluate current QPE capabilities, test and implement new methodologies, and develop new techniques for determining the best possible QPE in complex terrain regions.. Use the "lessons learned" to provide guidance on monitoring network design, data assimilation and modeling that can be applied CONUS to support NOAA's National Water Center (NWC) and National Weather Service (NWS) operations

HMT-QPE TEAM

- **Principal Members**
  - C. Campbell (ESRL/PSD – 1 FTE)
  - H. Chen (CIRA – 0.3 FTE)
  - R. Cifelli (ESRL/PSD – 0.05 FTE)
  - C. Hsu (ESRL/PSD – 0.1 FTE)
  - S. Matrosov (ESRL/PSD – 0.1 FTE)
  - D. Reynolds (CIRES – 0.25 FTE)
  - E. Sukovich (CIRES – 0.1 FTE)
  - Delbert Willie (CIRA – 0.3 FTE)
- **Collaborators**
  - V. Chandrasekar (CSU-CIRA)
  - A. Cross (MTR WFO)
  - K. Hondl (NSSL)
  - K. Howard (NSSL)
  - C. Kahler (WR)
  - C. Langston (NSSL)
  - S. Matrosov (CIRES)
  - D. Streubel (AKRFC)
  - Y. Zhang (OHD)

~2 FTE

HMT-QPE PLAN

- HMT-QPE Plan has 8 Tasks:
  1. **Gap-fill radar** (systematic approach to integrating gap-fill radar data into MRMS)
  2. **MPE evaluation** (performance relative to Mountain Mapper)
  3. **Precipitation downscaling** (utilize PRISM plus additional information to generate precipitation climatologies at sub-monthly time scales)
  4. **QPE demonstration planning** (integrate QPE evaluations and algorithm improvements into current and future HMT field program planning)
  5. **Algorithm comparisons** (MRMS and MPE as well as assess added value of CMORPH and SCaMPR)
  6. **QPE hydrology forcing** (test sensitivity of simulated runoff to QPE forcing)
  7. **QPE-QPF verification**
  8. **Satellite-ground QPE and numerical model QPF comparison**

HMT-QPE FY12 ACTIVITIES, MILESTONES, AND STATUS

Activity/Milestone/Deliverable	Quarter Due	Status
1. Test MPE and MRMS QPE algorithms at ESRL (QPE Plan Tasks 1-2)	Q2	C*
2. Evaluate performance of QPE algorithms in CA watersheds (QPE Plan Task 5) – Q4 S Prof/QPE evaluation at Cazadero	Q4	C*
3. Evaluate added value of gap-filling radar data in MRMS and MPE (QPE Plan Task 1-2)	Q4	C*
4. Develop downscaled precipitation tool (QPE Plan Task 3)	Q4	C*
5. Revised QPE Plan for HMT-SE (QPE Plan Task 4)	Q2	C
6. VPR correction - evaluate in MRMS	Q4	P
7. Conduct proof-of-concept studies for QPI (SFPUC and SCWA) and Frost Prediction (SCWA)	Q3	C*

* Further activity anticipated in FY13

ACTIVITY 1: MPE AND MRMS INSTALLATION AND TESTING

- **Huge effort to get systems up and running**
- Development of visualization tools
  - GFE, Google Earth, MET obect identification, NC View
- Debugging software
- Development of algorithms for file format and grid-type conversion
  - Lat-lon to HRAP, xmrg to netcdf and vise versa, xmrg-netcdf to MET
- Development of radar blockage files
  - KPIX
- Installation of software to generate radar accumulation files
  - C.O.D.E for MPE DPAs
- Development of scripts for batch processing
- Redefinition of directory structures to work with input data
- Development of common gauge data set for comparison of QPE products
- Comparison of results from the retrospective versions at ESRL to the NSSL real-time version (MRMS) and MTR (MPE) analyses
- Development and testing of software to read and process KPIX radar data

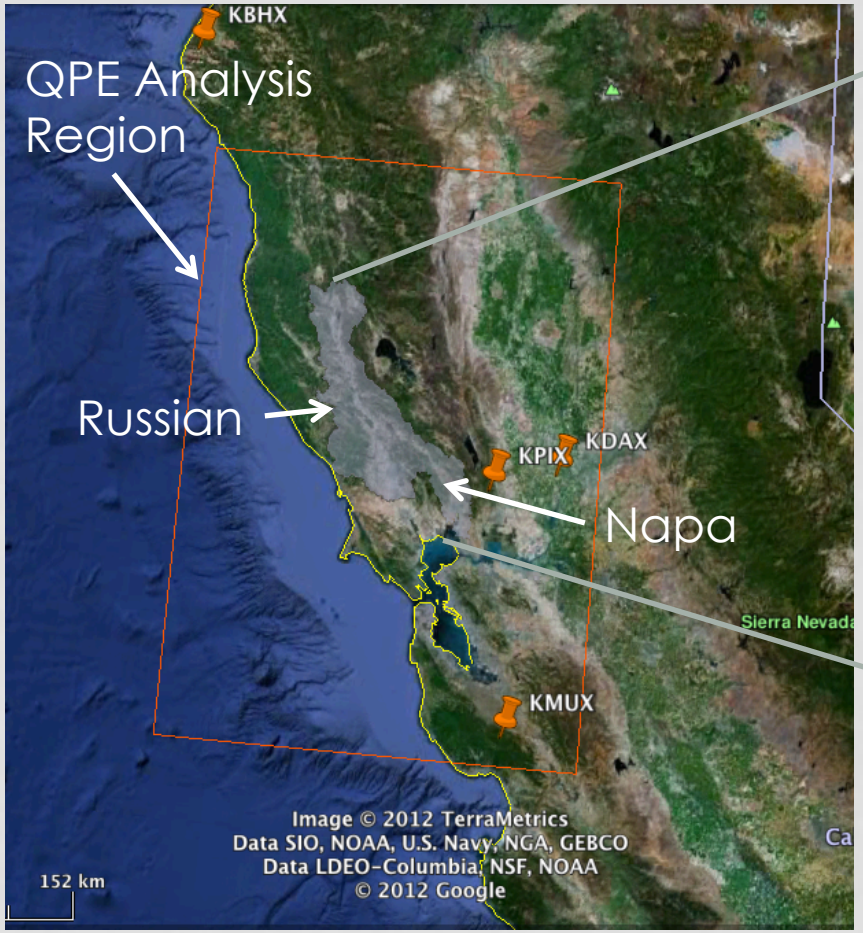
EVALUATION OF GAP-FILL RADAR IN RUSSIAN RIVER BASIN USING MRMS AND MPE

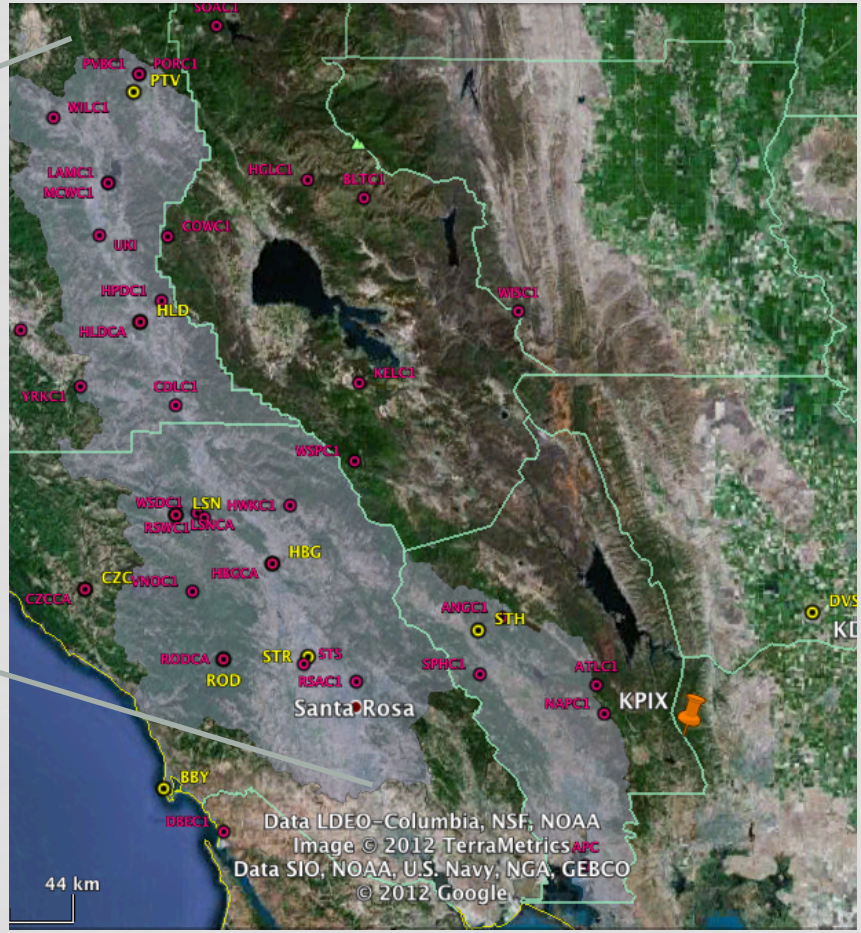
EXAMPLES OF FY12 ACTIVITIES 2, 3, 7

RUSSIAN RIVER QPE OBJECTIVES

- Sensitivity of QPE to KPIX radar data
- Comparison of radar-gauge QPE with CNRFC Stage IV QPE
  - to better understand performance of PRISM in selected precipitation events
- Comparison of QPE product suite from MRMS and MPE
  - determine which product(s) perform best and to identify where improvement to algorithm performance can be made
- Evaluation of spatial verification techniques for QPE

QPE EVALUATION REGION: RUSSIAN-NAPA RIVER BASINS

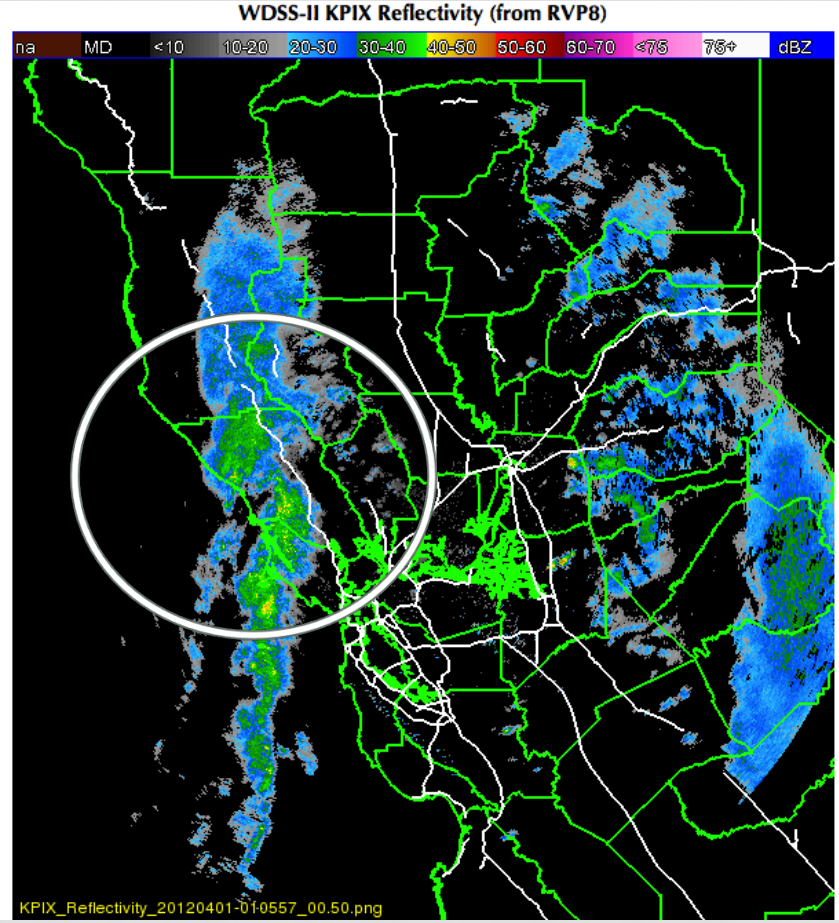




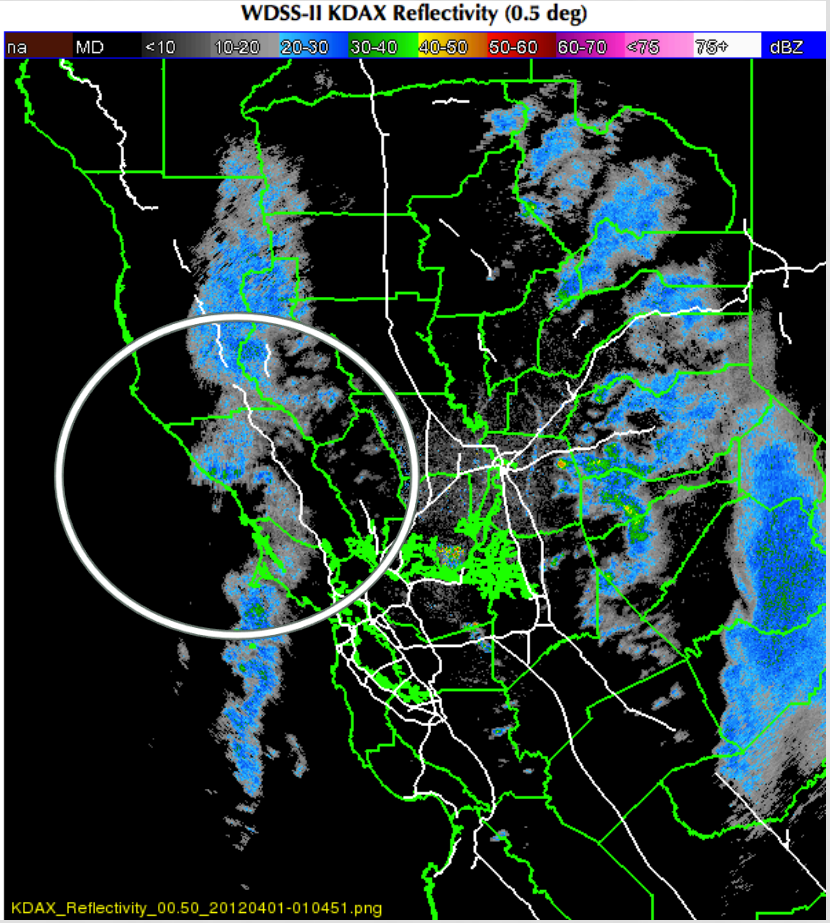
Red – analysis gauges
Yellow – independent gauges

KDAX VS KPIX RADAR REFLECTIVITY COVERAGE IN RUSSIAN RIVER BASIN

KPIX

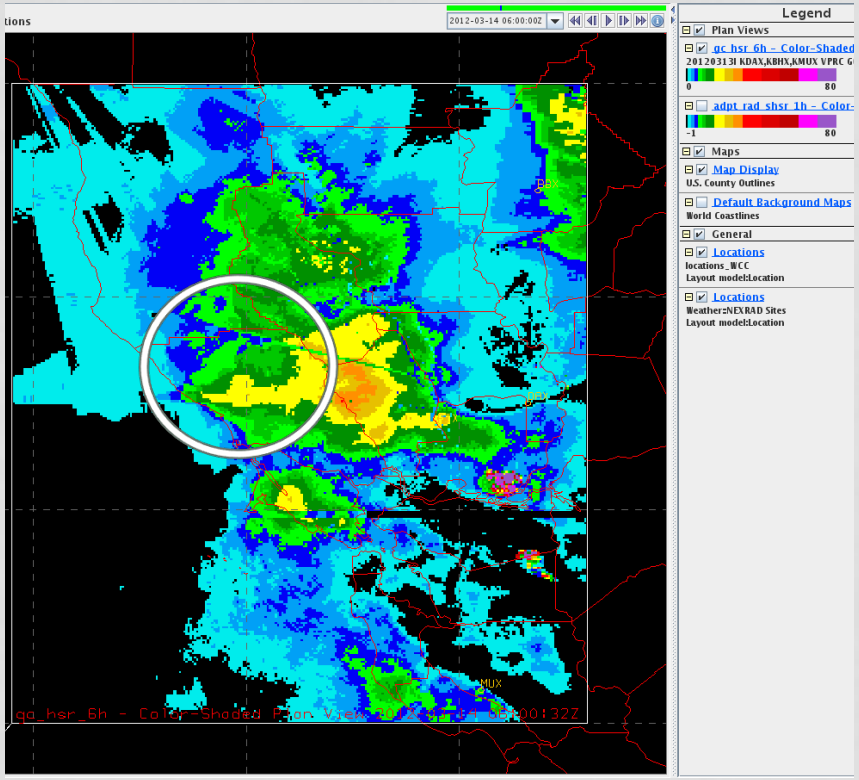


KDAX

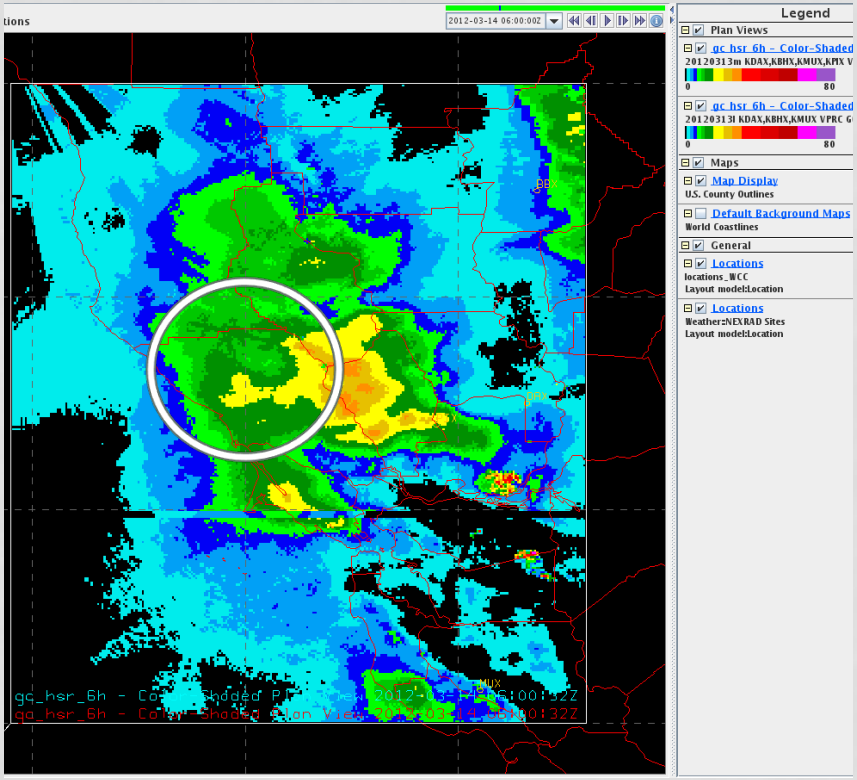


MARCH 14, 2012: MRMS 6 HOUR ACCUMULATION (00-06Z) GAUGE CORRECTED RADAR

KMUX, KDAX, KBHX

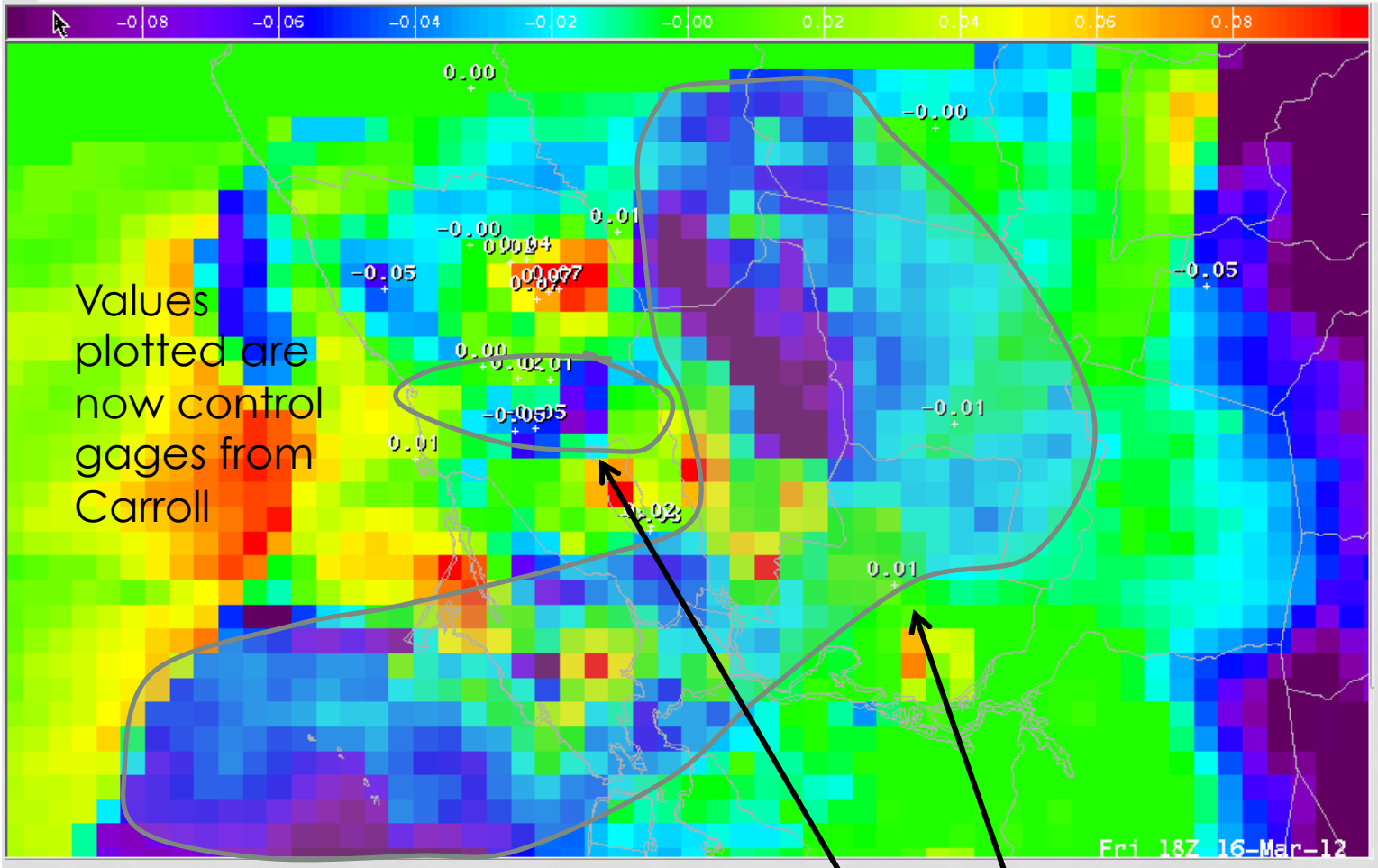


KMUX, KDAX, KBHX, KPIX



Displays generated using IDV

MRMS VPRGC WITH KPIX MINUS MPE MMOSAIC MTR 18-19Z 16 MAR 2012



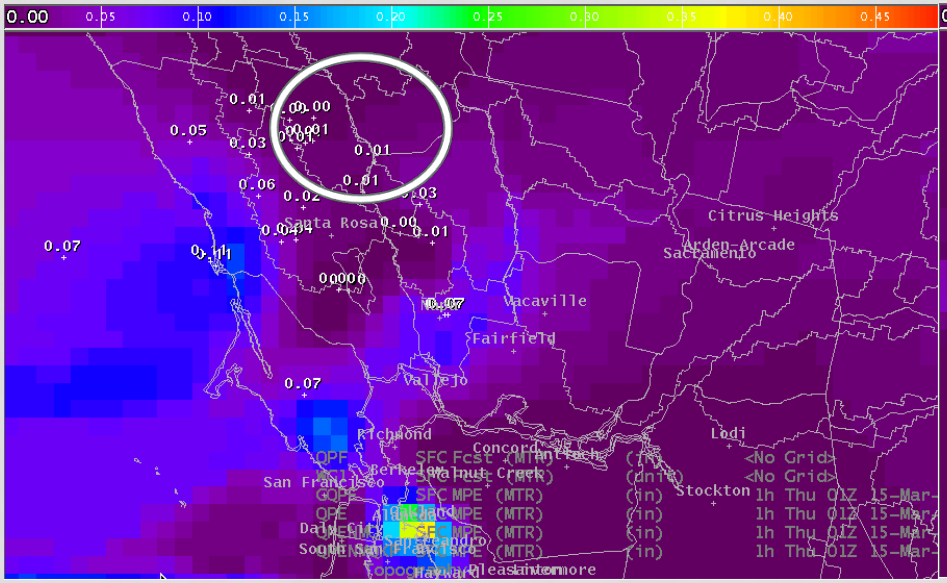
Values plotted are now control gages from Carroll

- GFE display
- Comparisons between MRMS and MPE are complicated by differences in methods to generate QPE

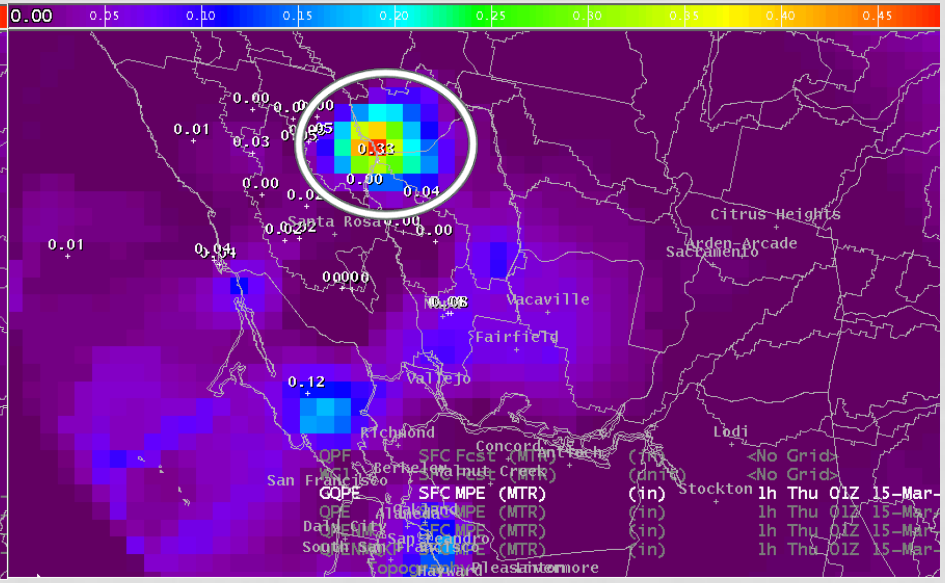
MRMS weights more on KDAX? whereas MPE uses KPIX-only?

MPE GMOSAIC 01-02Z 15 MAR 2012

ESRL

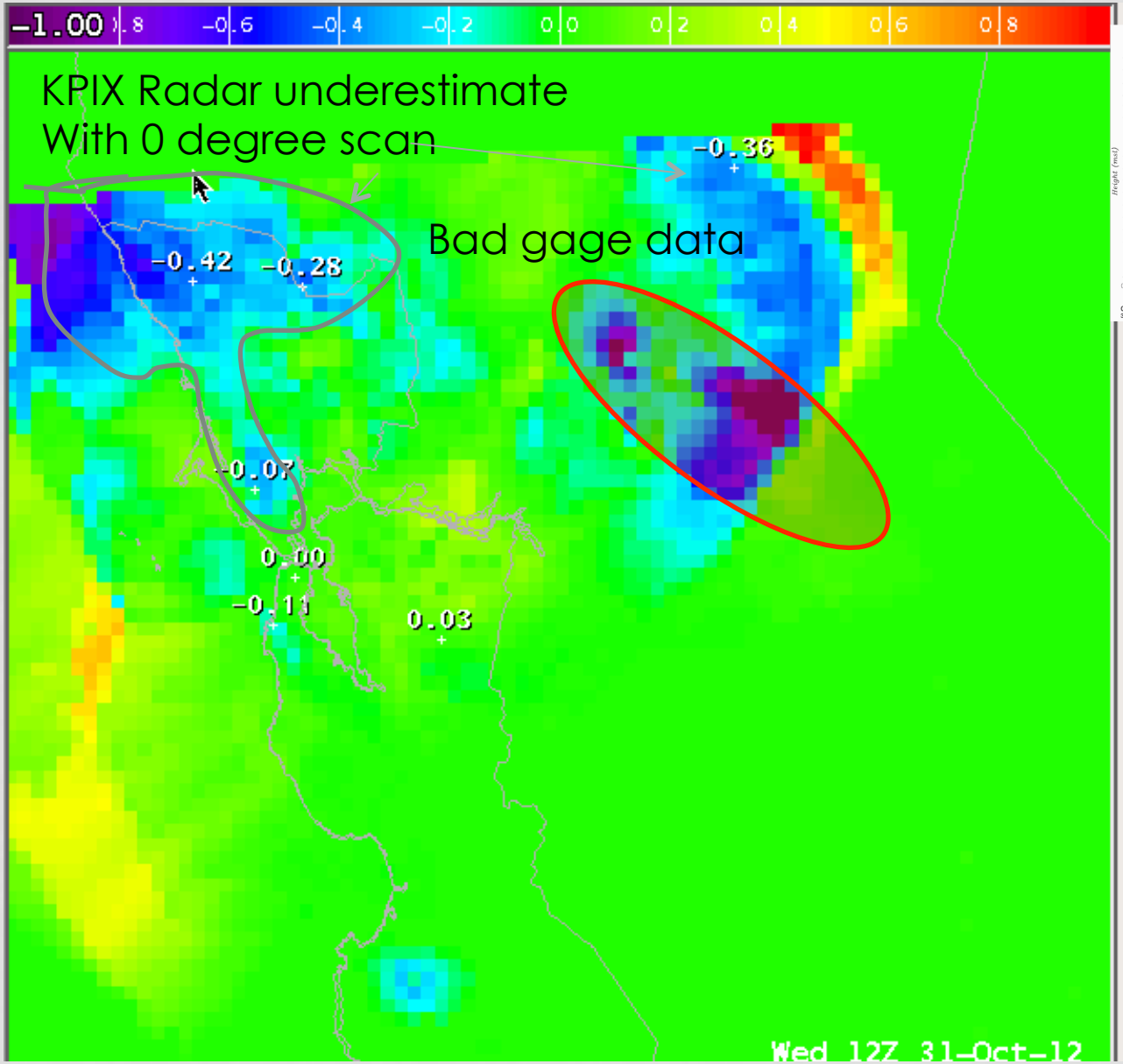


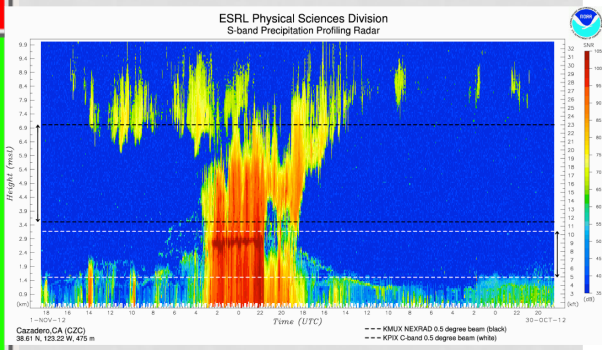
MTR



- GFE display
- St Helena gauge not in ESRL-generated QPE
- Common gauge set is critical for meaningful comparisons

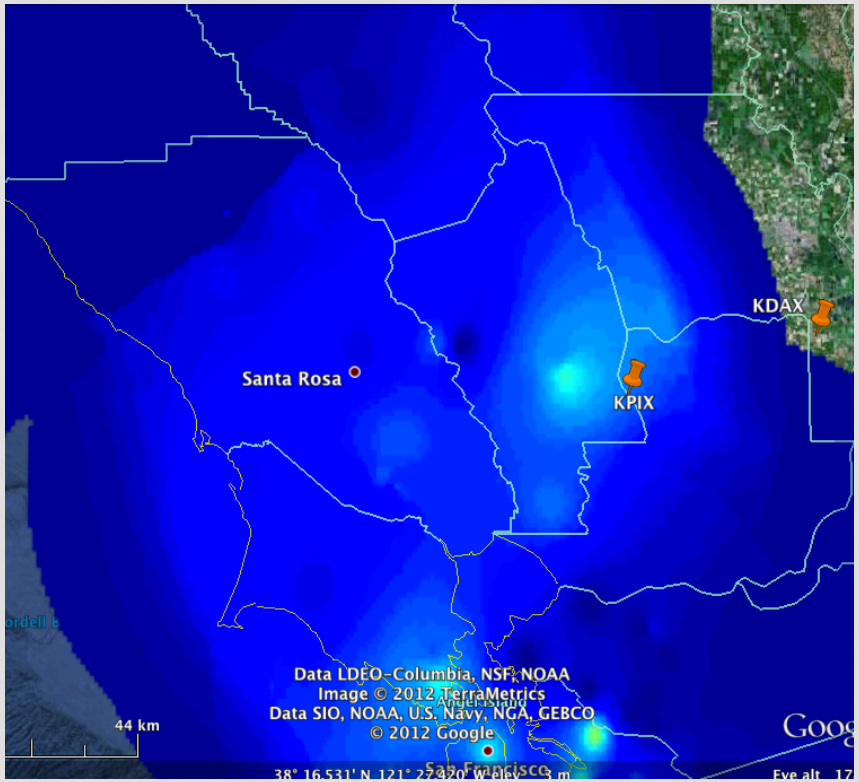
MMOSAIC-GMOSAIC 24 HR TOTALS ENDING 12Z 1 NOV 2012



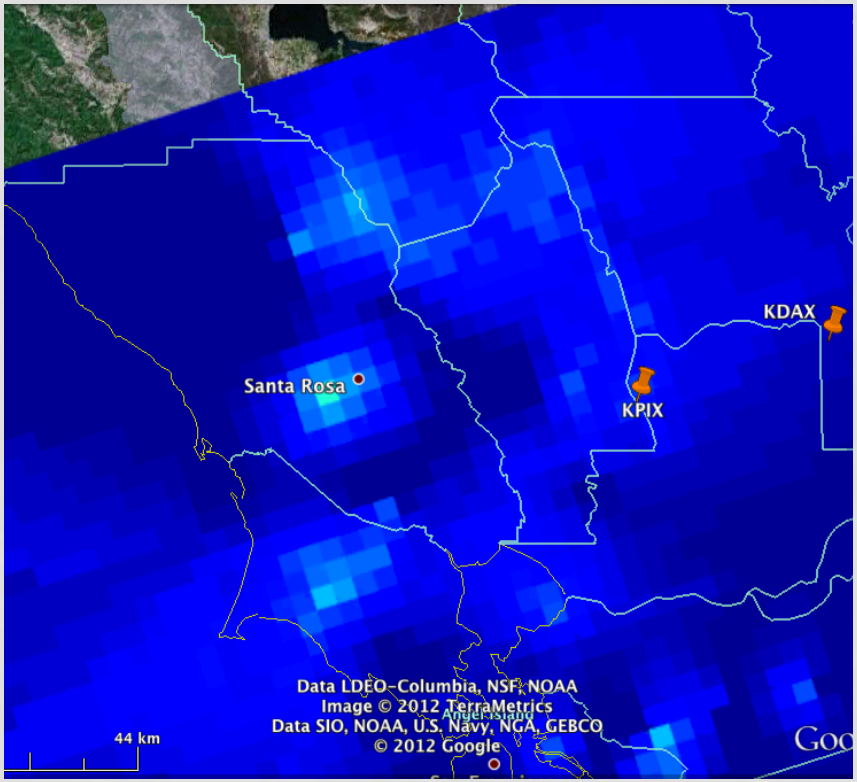


GOOGLE EARTH: MRMS VS MPE

MRMS (Gauge-only)



MPE (Gmosaic)



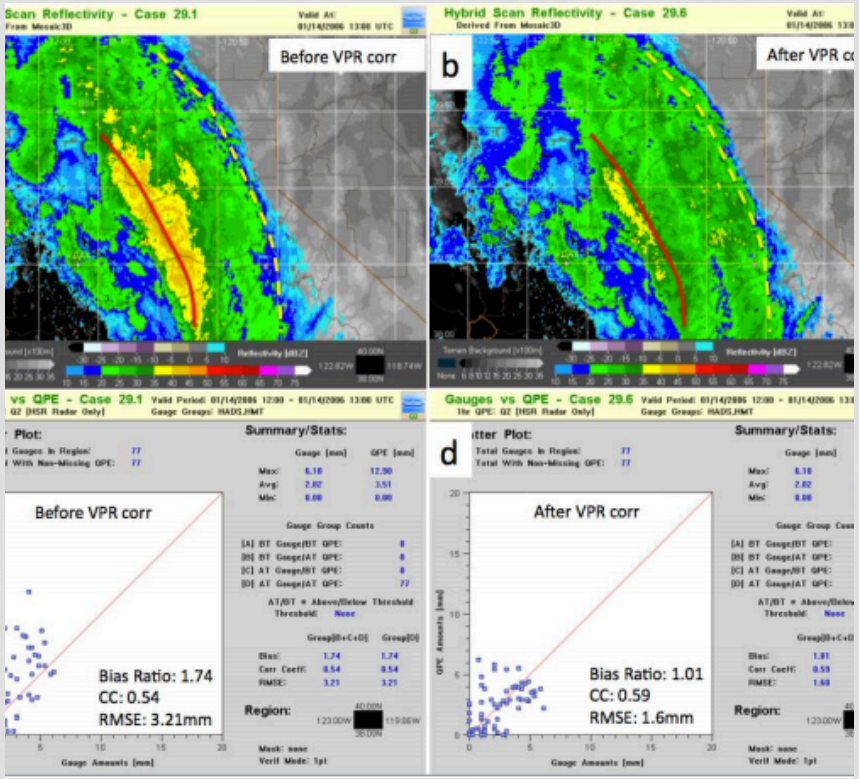
March 14, 2012 17Z: hourly accumulation

CURRENT STATUS FOR MRMS AND MPE ANALYSES

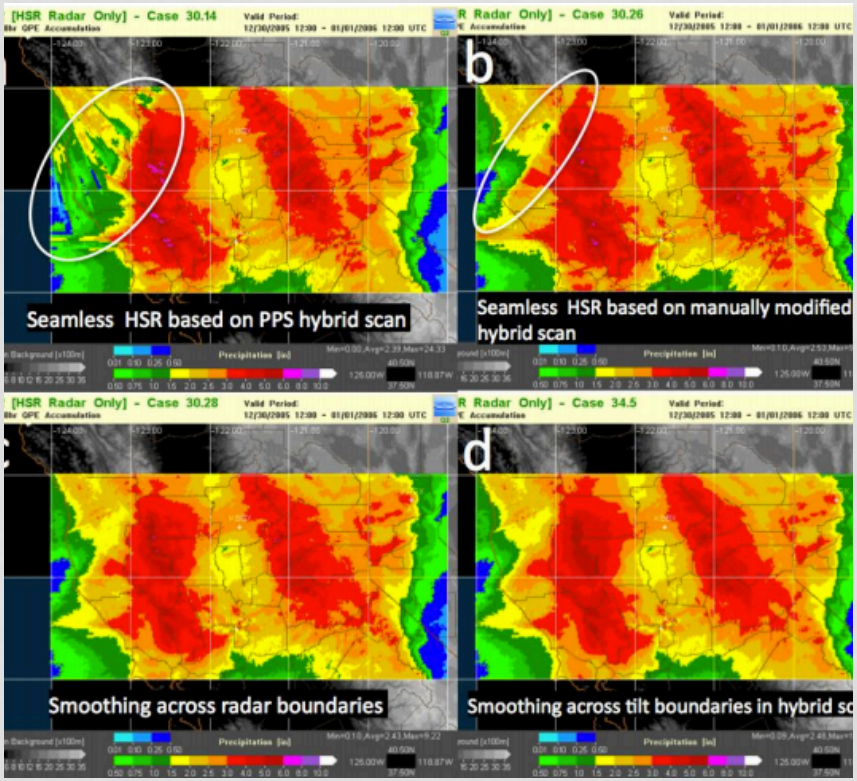
- Think we now can really look at KPIX influence using MRMS at ESRL
  - Plan to utilize QVS software at NSSL
- Status of ESRL MPE not clear
  - not using same gages as MRMS yet
  - Not clear ESRL MPE gage only (Gmosaic) sphere of influence same as used in MTR
  - ESRL MPE Mmosaic status unclear
- Move forward with ESRL MRMS with and without KPIX and use control gages for validation of KPIX influence
- Further testing needed with ESRL MPE

ESRL-NSSL COLLABORATION TO IMPROVE QPE IN MRMS

VPR correction



Improved radar mosaicing



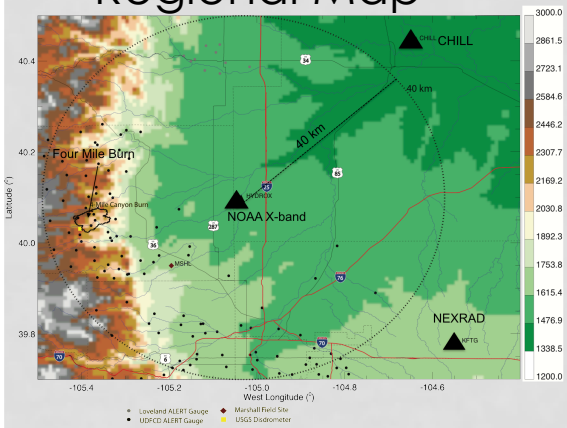
Zhang, J., Y. Qi, D. Kingsmill, and K. Howard, 2012: Radar-based quantitative precipitation estimation for the cool season in complex terrain: Case studies from the NOAA Hydrometeorology Testbed. J. Hydrometeor., in press.

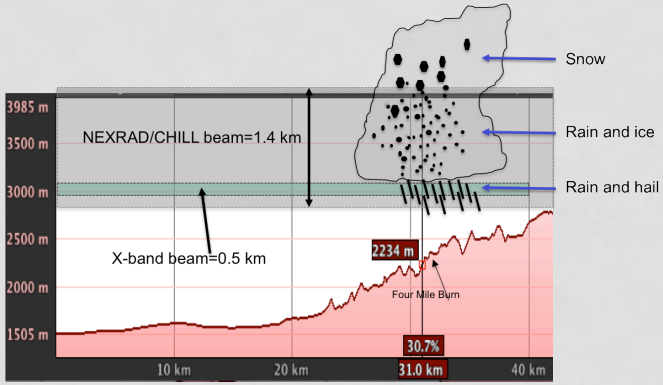
EVALUATION OF GAP-FILL RADAR IN FOUR MILE CANYON

EXAMPLE OF FY12 ACTIVITY 3

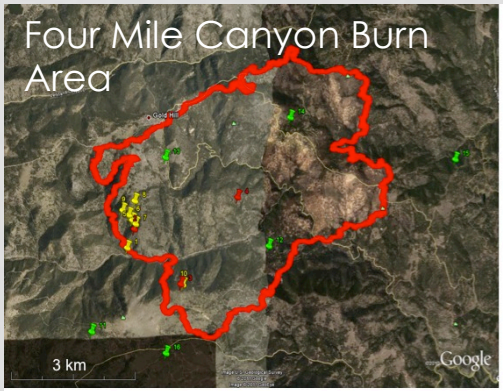
FOUR MILE CANYON QPE ANALYSIS: 13 JULY 2011

Regional Map

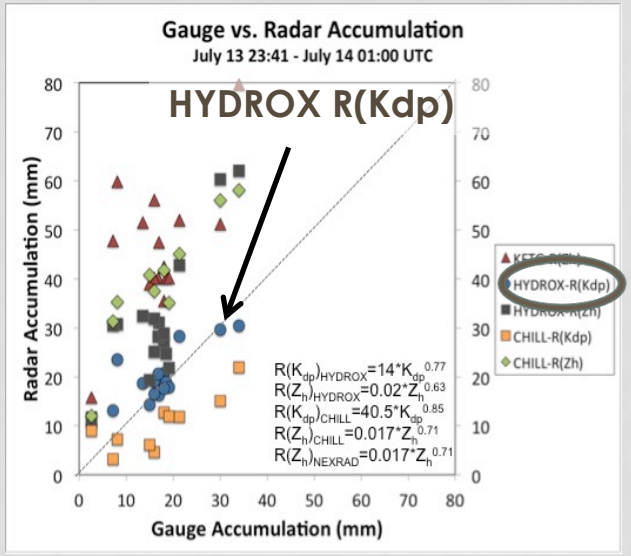




- July 13 flash flood in Four Mile Canyon
- Rain mixed with hail event
- 3 radars used in QPE comparison
  - *HYDROX (30km)*
  - *CHILL (70 km)*
  - *NEXRAD (75 km)*
- HYDROX provides best QPE
  - *Better resolution*
  - *R(Kdp) estimator superior to R(Z)*



Perimeter of Fourmile Canyon burn area with location of rain gauges indicated by colored pins. Green, yellow, and red colors correspond to ALERT, USGS, and NCAR gauges, respectively.



Matrosov, S., R. Cifelli, and D. Gochis, 2012: Measurements of heavy convective rainfall in presence of hail in flood-prone areas using an X-band polarimetric radar. *J. Appl. Meteor.* Climatol., in press.

R Cifelli, S Y Matrosov, D J Gochis, P Kennedy, J A Moody, 2011: Observations of Heavy Rainfall in a Post Wildland Fire Area Using X-Band Polarimetric Radar: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,

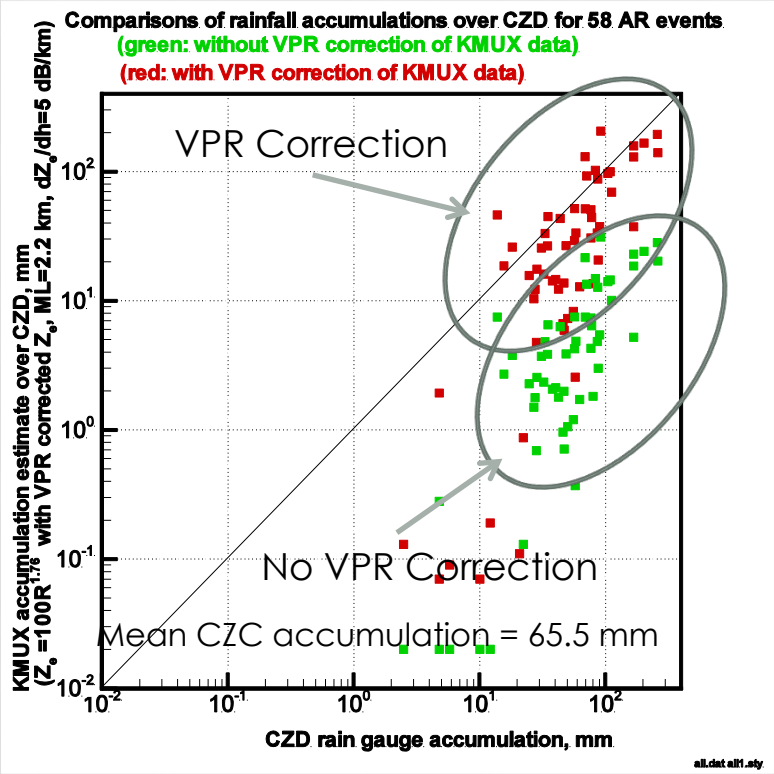
S.Y. Matrosov, R. Cifeli, D. Gochis, K. Clark, C. Campbell , J. Gibson, 2011: Using an X-band polarimetric radar for high resolution measurements of heavy rainfall in flood-prone areas, X-band Radar International Workshop, Delft, Netherlands

COMPARISON OF KMUX QPE AT CAZADERO USING VPR

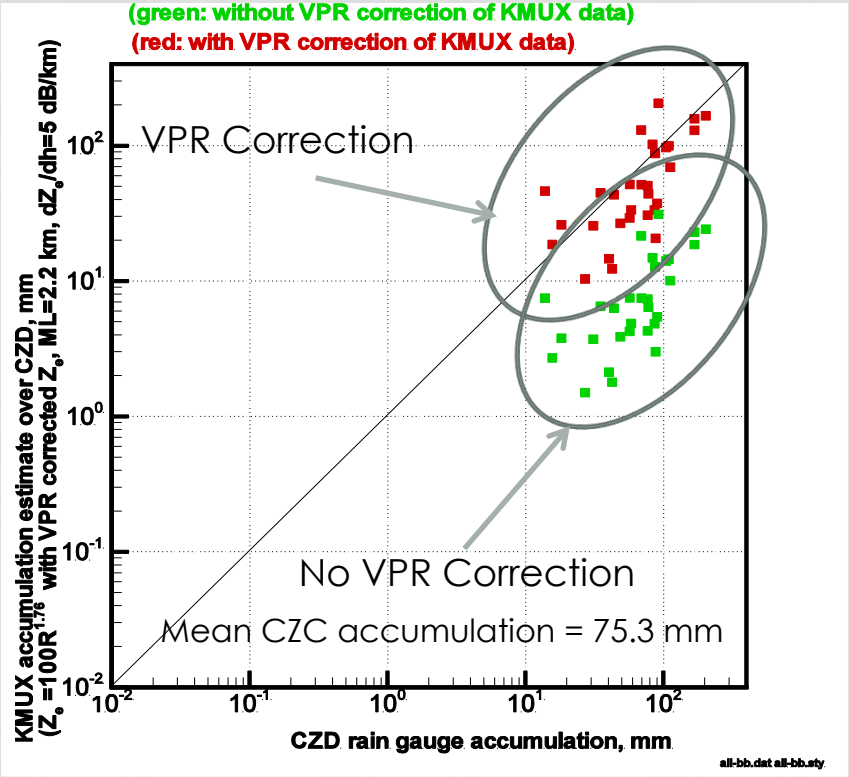
EXAMPLES OF FY12 ACTIVITIES 2 AND 6

COMPARISON OF KMUX RAINFALL AT CZC

All 58 AR events



30 AR events with BB fraction > 50%



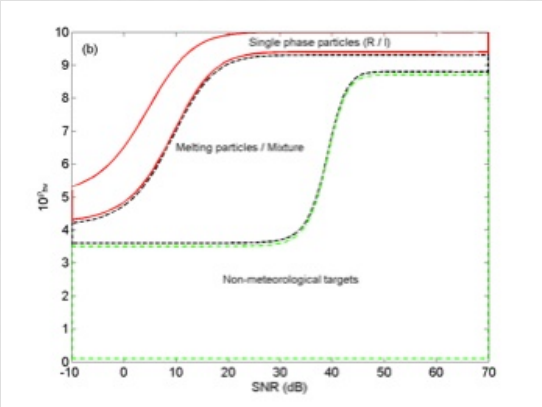
Rainfall estimated using $Z=100R^{(1.76)}$

GAP-FILL RADAR QPE IN THE AMERICAN RIVER BASIN

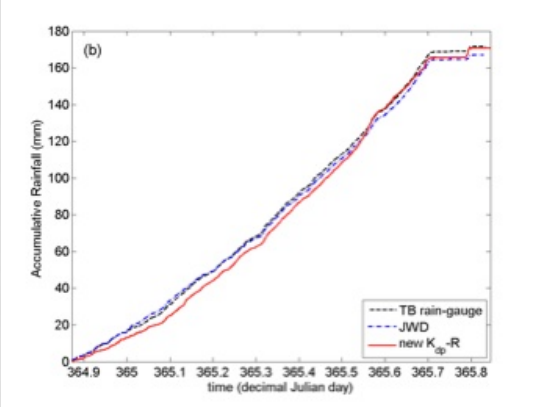
EXAMPLE OF ACTIVITY 3

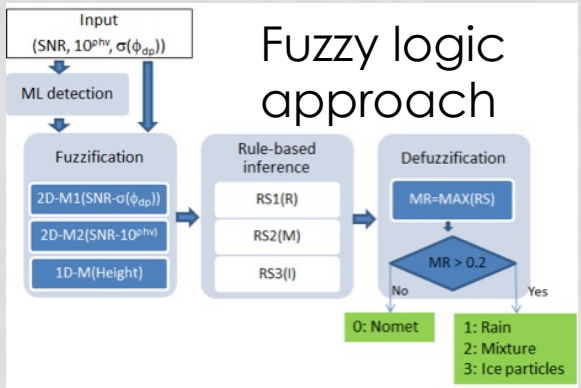
DEVELOPMENT OF NEW QC-HYDROMETEOR CLASSIFICATION ALGORITHM

Hydrometeor classification



Rainfall accumulation at CFX





Fuzzy logic approach

- New QC and hydrometeor classification technique developed using HYDROX data in the American River Basin
- Uses fuzzy logic technique based on magnitude of ρ hv,texture of Φ_{dp}, and SNR
- New method to estimate K_{dp}
- Methodology works well for QPE

Lim, S., R. Cifelli, V. Chandrasekar, and S. Matrosov, 2012: Precipitation classification and quantification using X-band dual-polarization weather radar: Application in the Hydrometeorology Testbed. *J. Atmos. Oceanic Technol.*, in review.

Chandrasekar,V., S Lim, R Cifelli, 2011: Principles and practical implementation for high resolution multi-sensor QPE: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,

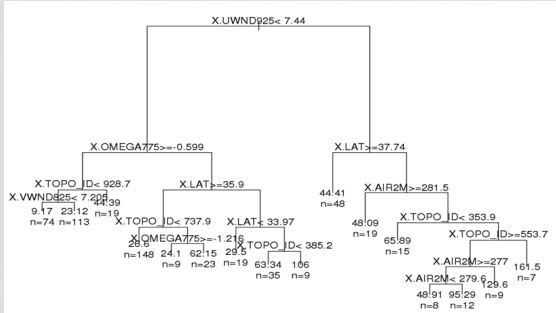
DEVELOPMENT OF PROTOTYPE PRECIPITATION DOWNSCALING MODEL

EXAMPLE OF FY12 ACTIVITY 4

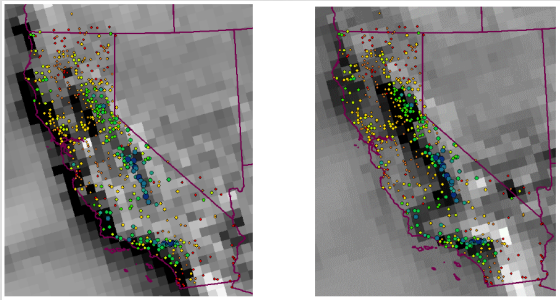
PRECIPITATION DOWNSCALING

- PRISM designed to capture precipitation gradients at monthly time scales
  - Used to downscale low resolution QPE and QPF
  - Issue is how accurately it can be applied at shorter time scales and in areas with limited gauge coverage
    - HMT work has shown PRISM cannot adequately capture spatial variations in the orographic precipitation gradient during years when more than 70% of the precipitation occurred on days with extreme events
- New prototype downscaling method uses topographic factors plus meteorological variables, such as u, v, Ω, condensation rate, bulk water vapor transport, etc.
- Machine learning theory used to "weight" different factors

Hierarchical structure for variable input



Correlation of omega and rainfall

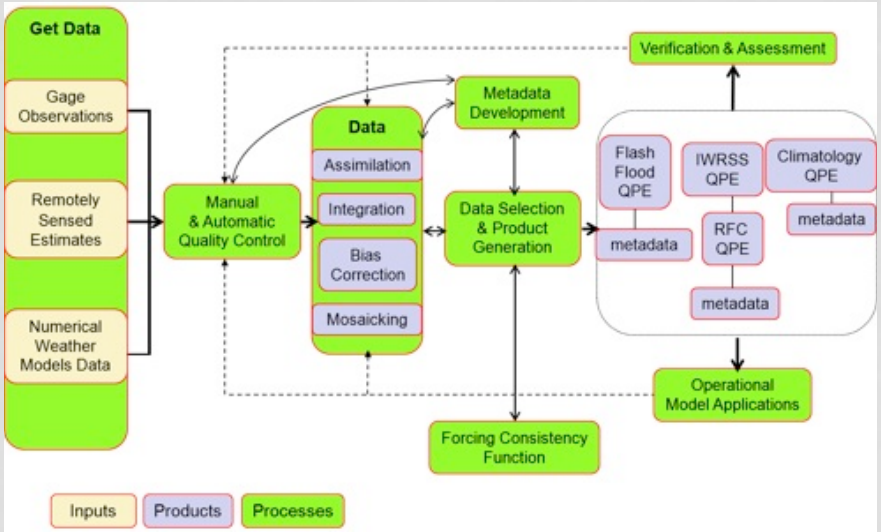


Plot of Precipitation at the Gauge Stations on Omega at 900mb Level

Plot of Precipitation at the Gauge Stations on Omega at 775mb Level

Hsu, C., R Cifelli, R J Zamora, L E Johnson, 2011: Toward the Estimation of High-Resolution Daily Precipitation in Complex Regions - The Study of Intertwined Physiographic, Vegetative, and Climatologic Factors for PRISM Enhancement: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,.

OTHER FY12 HMT-QPE ACTIVITIES NOT REPRESENTED IN ACTIVITY TABLE



- Co-hosted data fusion workshop at OHD in February 2012
- Working with NOAA SGPMS on NASA GPM Proving Ground focused on precipitation data fusion
  - Conducted in coordination with HMT

Chandrasekar, V., and R. Cifelli, 2012: Concepts and principles of rainfall estimation from radar: Multi-sensor environment and data fusion. *Indian J. Radio and Space Physics*, **41**, 389-402.

FY12 – FY13 R2O ACTIVITIES

- Engagement with HMT partners across NOAA
  - NSSL, OHD, and NWS field offices involved with MRMS and MPE retrospective analyses
    - Testing new algorithms and evaluation of QPE using development systems provides real opportunity for establishing "*center of excellence on QPE in complex terrain*"
      - Anticipation is that lessons learned could translate to operations versions of QPE systems
      - Desire from NESDIS STAR and CPC to participate in this effort

FY12 CHALLENGES

- MPE and MRMS software installation and testing took much longer than anticipated
  - Do not have MRMS source code
  - Rely heavily on NSSL for assistance
  - Easy to lose sight of long term goals
- Lost momentum due to employee turnover
  - American River Basin work transitioned to Russian River Basin
- Lot of QPE activities with a lot of participants
  - Not everyone is working at ESRL
  - Regular communication is key to staying on task

FY13 PLANS FOR HMT-QPE

- Revise QPE Plan
- Continue evaluations in Russian River basin using MRMS and MPE
  - Support from SCWA (IWRSS?)
  - Collect more data
  - Use MRMS to assess impact of KPIX
  - QPE forcing for hydrologic simulations
  - Continue working on MPE (Mmosaic)
- Host "development" version of MRMS and test/improve algorithms
  - VPR correction
  - Dual pol rainfall estimation
  - Spatial verification
  - Data fusion (CMORPH, SCaMPR, MPE Mmosaic, others)
- Conduct evaluations in HMT-SEPS
  - Equipment deployed in late spring
  - Begin collection of all data sets needed for evaluation
    - Work with NESDIS, NWS, and OAR partners to develop common "pre-processing"
- Precipitation downscaling
  - IWRSS sees potential in this methodology
  - Issue is available resources to do the work

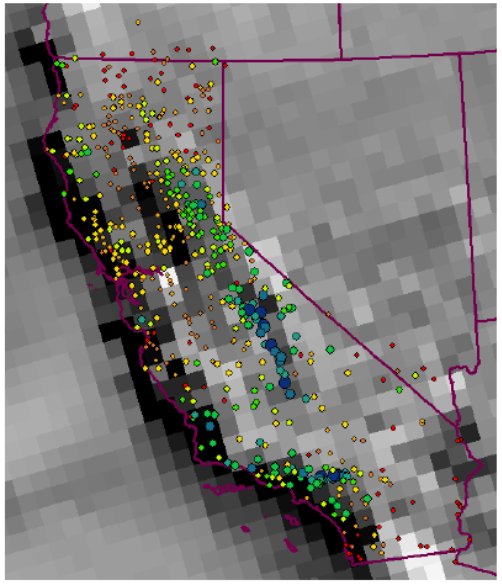
RISKS FOR FY13 HMT-QPE ACTIVITIES

- Continued progress requires strengthening partnerships
  - QPE evaluations and testing require close coordination with NSSL, OHD and others
    - How to do this in a limited budget environment
  - Partners can only engage when time is available
- A lot of efforts with limited funding
  - IWRSS support for precipitation downscaling work and QPE evaluations have been supported by IWRSS, SCWA, and base funding
    - IWRSS and HMT base support in FY13 have large uncertainties
    - SCWA support for QPE through July 2013
  - Limited staff resources
    - Most team members (including the QPE lead) are involved with a number of other projects
    - Task prioritization will be required

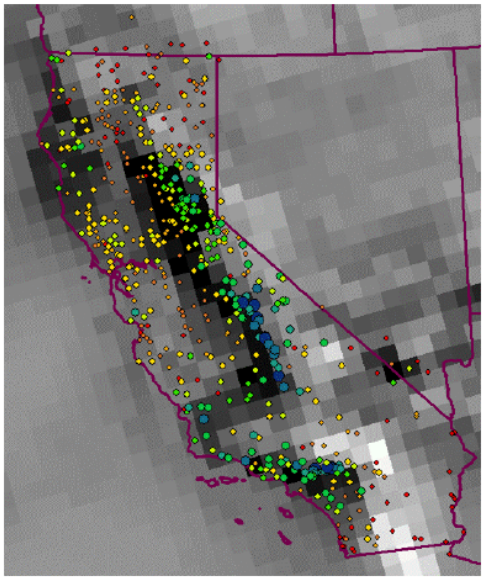
BACKUP SLIDES

UPGRADING PRISM FOR HIGH RESOLUTION PRECIPITATION ESTIMATION PURPOSES USING A MACHINE LEARNING THEORY

Applications of NARR Data



Plot of Precipitation at the Gauge Stations on Omega at 900mb Level



Plot of Precipitation at the Gauge Stations on Omega at 775mb Level

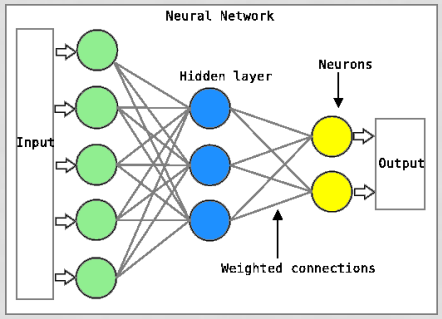
Fig. Precipitation on Dec. 19, 2010 and Omega

- At 775 mb level, vertical motion occurrence (dark grids) shows correspondence to the locations of heavy precipitation (blue and green points)
- For the coastal mountain range, Ω at the 900 mb level shows highly correspondence to heavy rainfall occurrence in the costal zones

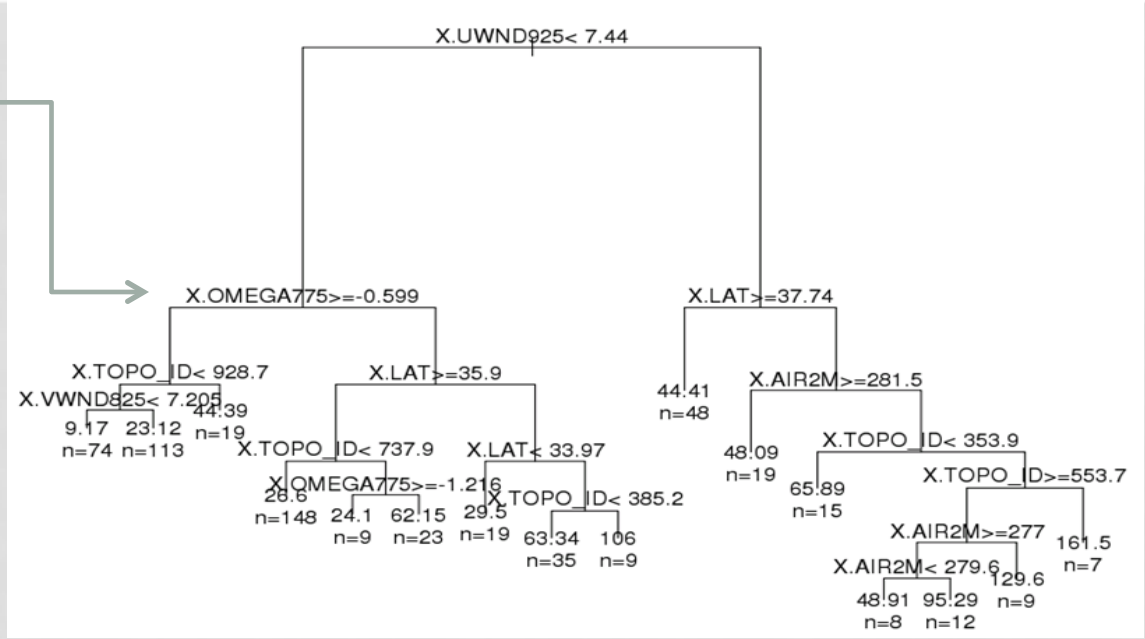
*Implications: **Omega** can be one of the important variables for estimating high resolution daily climatology.*

UPGRADING PRISM FOR HIGH RESOLUTION PRECIPITATION ESTIMATION PURPOSES USING A MACHINE LEARNING THEORY

When *u* is small, omega plays a key role in determining the precipitation intensity.



V.S.

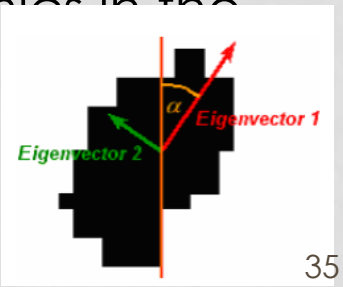


The predictor variables such as air motion, temperature, wind speed, location, and topographic variables are all integrated for analysis with a classification tree. The **tree-like precipitation estimation system** forms a **hierarchical structure** for interpreting the **non-linear relationship** between precipitation and the predictor variables.

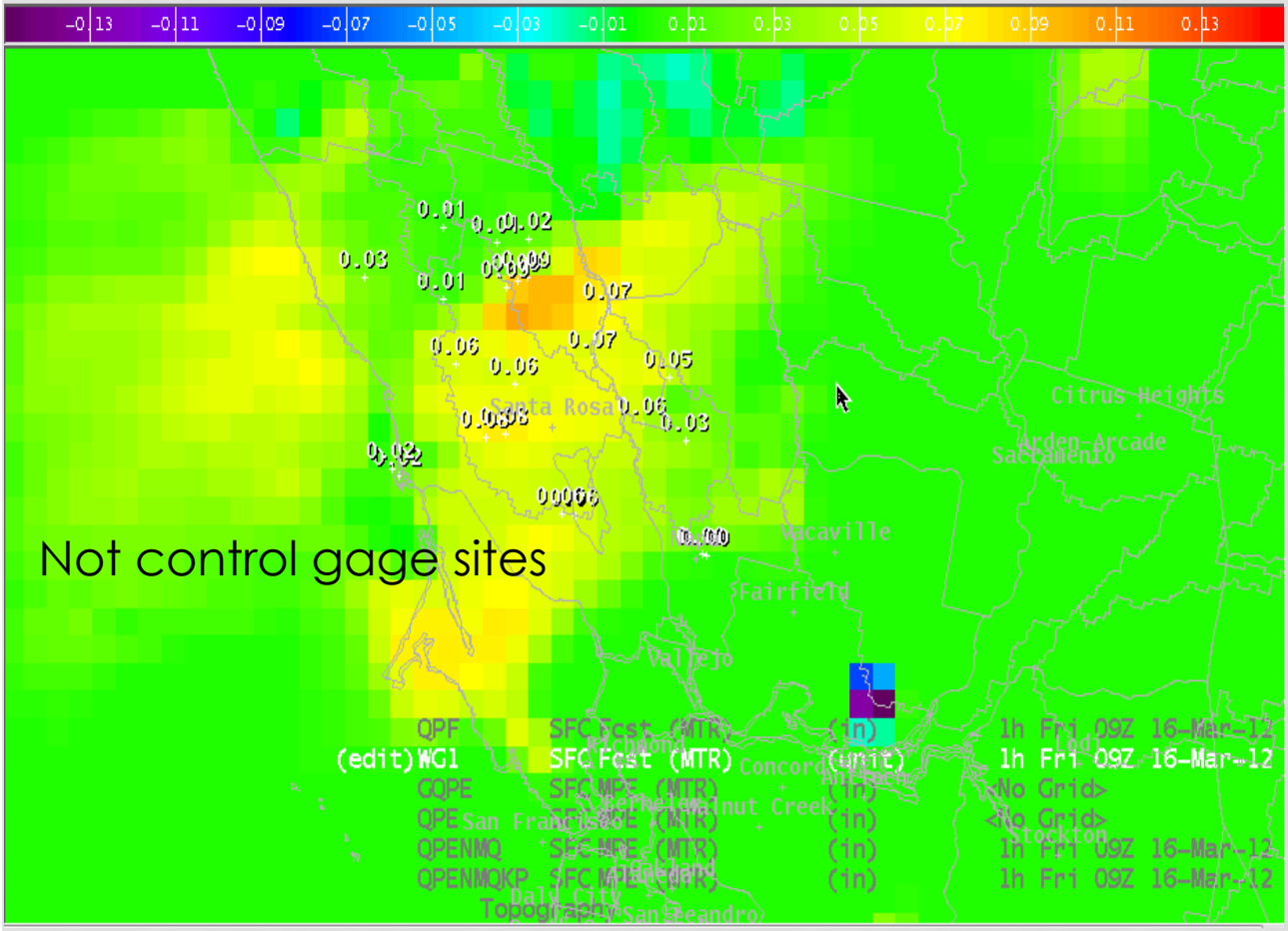
Upgrading PRISM for High Resolution Precipitation Estimation Purposes Using a Machine Learning Theory

Featured Work toward High Resolution Precipitation Estimation:

1. Downscaling NARR variables based on the height rise/ descent of the air parcel in the sub-grids. A mountain geometry index will be developed for application in interpreting the rise and descent of air flow.
2. Parameterizing microphysical phenomenon such as reverse rain shadow, bulk water vapor transport, blocking-induced frontal splitting and merging, and low-level flow blocking, etc. and inserting them into the decision tree model.
3. Apply object-based information (eCognition Application) to model storm movement and condensation dynamics in the geomorphologic context.

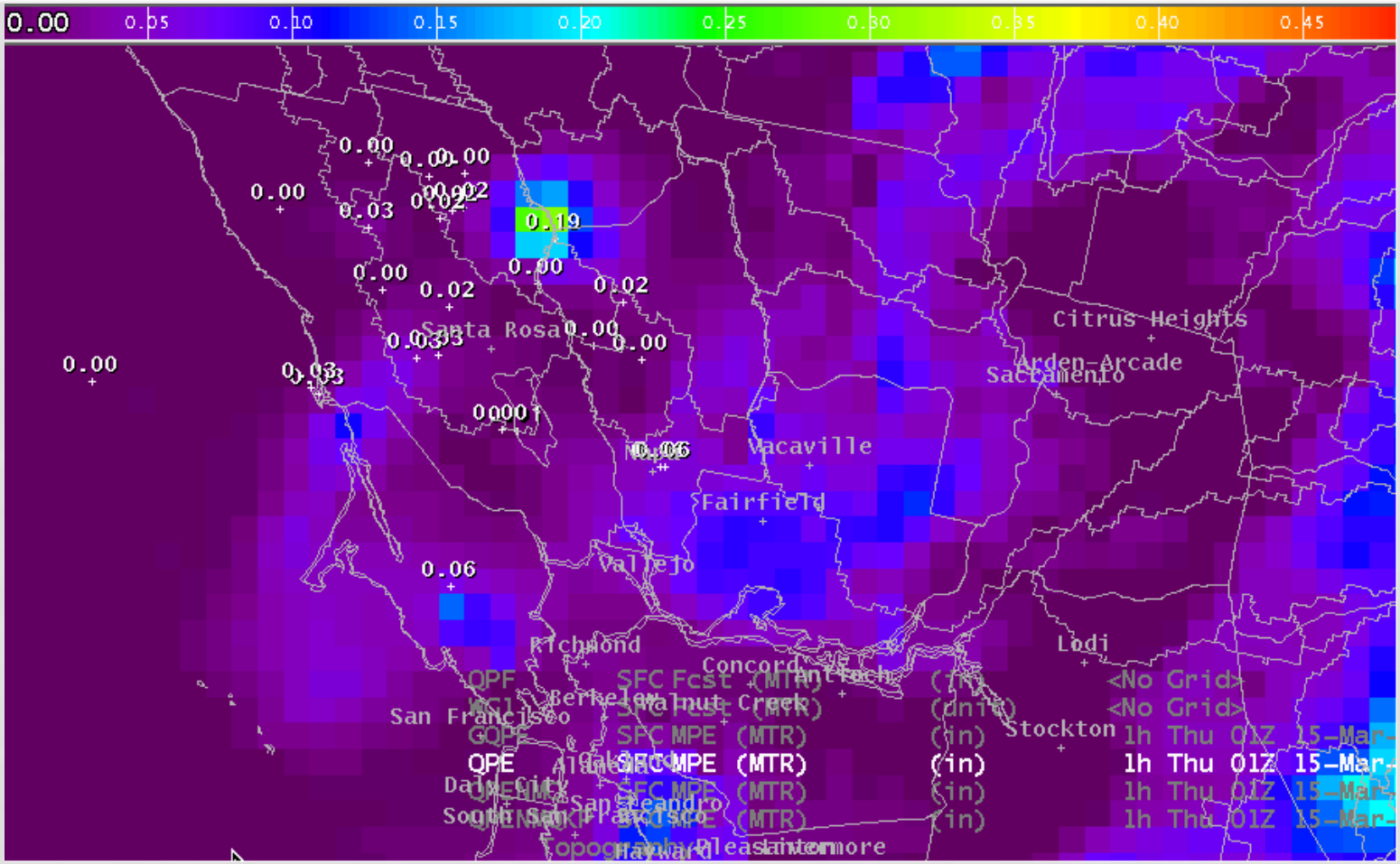


GFE DISPLAY: MRMS VPRGC WITH KPIX MINUS NO KPIX 09-10Z 16 MAR 2012



- Analysis includes KDAX, KMUX, KBHX, and KPIX radars
- KPIX provides better coverage and more precipitation over Sonoma County compared to using KDAX

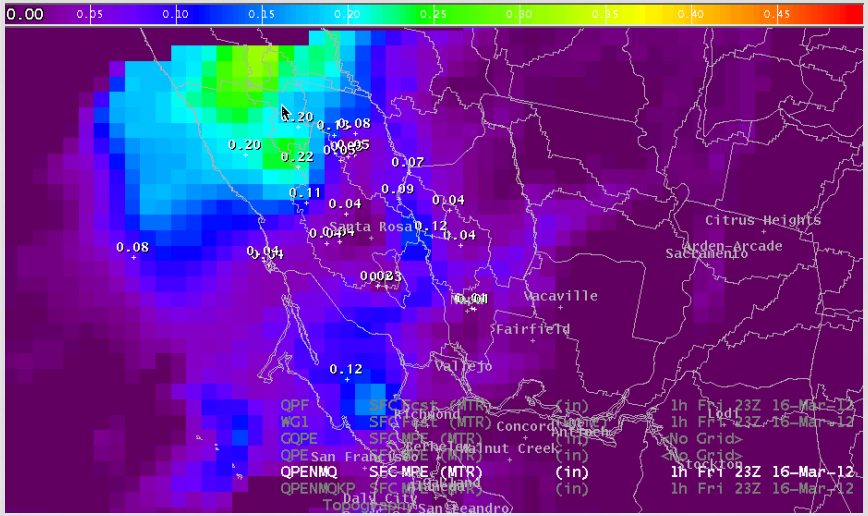
GFE: MPE MMOSAIC MTR 01-02Z 15 MAR 2012



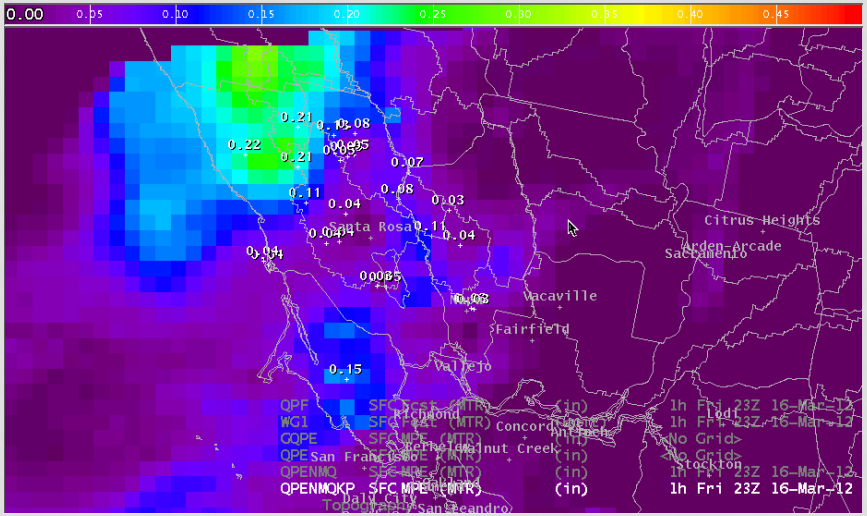
Not control gage sites

GFE: MRMS VPRGC
23-00Z 16-17 MAR 2012

No KPIX



With KPIX



- KPIX appears to be having little influence over NW Sonoma County
- Gauge weighting relative to radar?

HMT-QPE PUBLICATIONS

- **FY12 Publications**
  - Chandrasekar, V., and R. Cifelli, 2012: Concepts and principles of rainfall estimation from radar: Multi-sensor environment and data fusion. *Indian J. Radio and Space Physics*, **41**, 389-402.
  - Matrosov, S., R. Cifelli, and D. Gochis, 2012: Measurements of heavy convective rainfall in presence of hail in flood-prone areas using an X-band polarimetric radar. *J. Appl. Meteor.* Climatol., in press.
  - Lim, S., R. Cifelli, V. Chandrasekar, and S. Matrosov, 2012: Precipitation classification and quantification using X-band dual-polarization weather radar: Application in the Hydrometeorology Testbed. *J. Atmos. Oceanic Technol.,* in review.
  - Zhang, J., Y. Qi, D. Kingsmill, and K. Howard, 2012: Radar-based quantitative precipitation estimation for the cool season in complex terrain: Case studies from the NOAA Hydrometeorology Testbed. J. Hydrometeor., in press.
- **FY12 Presentations**
  - R Cifelli, S Y Matrosov, D J Gochis, P Kennedy, J A Moody, 2011: Observations of Heavy Rainfall in a Post Wildland Fire Area Using X-Band Polarimetric Radar: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,
  - C Hsu, R Cifelli, R J Zamora, L E Johnson, 2011: Toward the Estimation of High-Resolution Daily Precipitation in Complex Regions - The Study of Intertwined Physiographic, Vegetative, and Climatologic Factors for PRISM Enhancement: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,.
  - C V Chandra, S Lim, R Cifelli, 2011: Principles and practical implementation for high resolution multi-sensor QPE: 2011 Amer. Geophys. Union Annual Meeting, San Francisco, CA,
  - S.Y. Matrosov, R. Cifeli, D. Gochis, K. Clark, C. Campbell , J. Gibson, 2011: Using an X-band polarimetric radar for high resolution measurements of heavy rainfall in flood-prone areas, X-band Radar International Workshop, Delft, Netherlands