WORLD METEOROLOGICAL ORGANIZATION

JOINT MEETING OF
CBS EXPERT TEAM ON SURFACE-BASED REMOTELY-SENSED OBSERVATIONS
(Second Session)
AND
CIMO EXPERT TEAM ON OPERATIONAL REMOTE SENSING
(First Session)

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WEATHER RADAR OPERATIONS, STATUS, ISSUES, REQUIREMENTS FOR DATA EXCHANGE AND PLANS

Operational Developments

Development of Polarization Technology

(Submitted by Richard Ice, WSR-88D Radar Operations Center, Norman Oklahoma USA)

SUMMARY AND PURPOSE OF DOCUMENT

Provides a state of the technology report on Polarimetric Poppler Meteorological Radar including a summary of the United States' WSR-88D Polarimetric Upgrade.

ACTION PROPOSED

1. The Joint Meeting is invited to review the information contained in the document.

SUMMARY OF WSR-88D NETWORK UPGRADE

Design Development

The US NOAA National Severe Storms Laboratory (NSSL) science and engineering team installed a prototype polarimetric WSR-88D on the research radar KOUN 1997. As a result of that effort, the NSSL team recommended several key design features for a production polarimetric WSR-88D. These related to the fundamental polarimetric approach, the antenna modification, and calibration. Full Reports on the NSSL research and recommendations can be found at the following links:

http://publications.nssl.noaa.gov/wsr88d_reports/2pol_upgrades.pdf
http://publications.nssl.noaa.gov/wsr88d_reports/Modifications%20to%20the%20Research%20WSR-88D%20To%20Obtain%20Polarimetric%20Data.pdf
http://publications.nssl.noaa.gov/wsr88d_reports/Calibration_and_Performance_Analysis.pdf
http://publications.nssl.noaa.gov/wsr88d_reports/SHV_statistics.pdf
http://publications.nssl.noaa.gov/wsr88d_reports/ZDR-Rpt2.doc
http://publications.nssl.noaa.gov/wsr88d_reports/RPT_DoNotDestroy.doc

The NSSL engineers chose the Simultaneous Transmit and Receive (STAR) method for generating the additional (vertical) polarization channel. This, as opposed to the alternating approach, allowed the system to retain the baseline volume acquisition times without reducing the number of samples for each parameter. This also avoided potential hardware cost and recurring logistics and maintenance issues related to the fast alternating switch.

The NSSL team also chose to retain the baseline three strut feed support and waveguide assembly in order to keep antenna side lobe levels low. For the prototype, the team replaced the baseline horizontally polarized feed assembly with a new ortho-mode transducer and feed supplied by the original manufacturer. The trade off in terms of bias in differential reflectivity due to the asymmetric strut configuration was deemed acceptable.

The final primary design decision related to differential reflectivity calibration. The traditional method in the research community and early operational systems is to vertically point and rotate the antenna in light precipitation. The WSR-88D antenna pedestal baseline design does not support this approach without costly modifications. Also, taking an operational radar off-line to conduct calibration during precipitation events negatively impacts forecast and warning operations. The NSSL team recommended a so called “Engineering Calibration” based on careful power measuring and signal path loss measurements using instruments traceable to standards. The contractor team implemented a version of this approach.

Present Development and Deployment Status

The WSR-88D polarimetric upgrade has entered the production and deployment phase following several years of development and testing, including integration and engineering testing on the KOUN research radar co-located at the WSR-88D Radar Operations Center in Norman OK. The production upgrade kit was designed by a commercial team, working in close cooperation with US government experts at NSSL, National Weather Service, and the Radar Operations Center. It is of the simultaneous transmit and receive type (STAR). The existing 28 foot (8.53 m) parabolic reflector is modified by replacing the single horizontally polarized transducer/feed assembly with a new Ortho-mode transducer and feed. The antenna design retains the existing three strut approach but utilizes all new waveguides, support strut, and feed assembly mounts.

Design particulars include two antenna elevation arm mounted units, the RF Pallet, and Antenna Mounted Electronics (AME). The RF Pallet functions include power division via a variable phase power divider, appropriate directional couplers for calibration and monitoring, transmit – receive isolation via circulators and TR limiters, electromagnetic interference rejection filters, and low noise amplification. The interference rejection filters are fixed tuned, custom selected for each site frequency. The variable phase power divider allows for computer controlled selection of any combination of H and V transmit power at the output, but is normally set for 50% power in each channel. It is capable of supplying near 100% in either the horizontal or vertical transmit channel, a feature useful for supporting an external calibration method such as cross polarization power. The AME enclosure is climate controlled via a Peltier cooler and includes the RF to IF down conversion function and all necessary built-in-test equipment for establishing and maintaining calibration and monitoring system health.

Pedestal modifications feature a new four channel rotary joint for supplying RF and IF signals. The existing slip ring assembly was retained and used for supplying AC power for the new antenna mounted equipment. The four rotary joint channels are used for: (1) transmit pulse, (2) STALO from the existing RF generator located in the ground equipment shelter, (3) Horizontal IF, and (4) Vertical IF.

The baseline digital receiver and signal processor (Vaisala/Sigmet RVP8) and system control computers were retained. The RVP8 digital receiver was reconfigured to employ dual channel inputs for the H and V IF signals.

An extensive software development was necessary in order to integrate the baseline, custom, user software into the available RVP8 dual polarization processing features. This was accomplished by the contractor team and extensively tested by a joint contractor – government team in Norman OK over approximately a two year period. The software includes a straightforward clutter filtering approach for the polarimetric variables which is a modification of the Sigmet Gaussian Model Adaptive Processing (GMAP) clutter filter. While the baseline, non-polarimetric WSR-88D signal processing features an automatic clutter identification function, this feature was not incorporated into the polarimetric software and will be added in the first post development software release from the Radar Operations Center in the 2012 calendar year.

Following a beta test period with several fielded radars, full scale deployment began in the Fall of 2011. By the end of 2011, approximately 20 network radar sites will be modified with polarimetric capability.

Test and Evaluation Process

The contractor conducted engineering and integration tests, witnessed by US government experts, at their factory locations and on the prototype KOUN radar in Norman Oklahoma. The meteorological data quality was closely evaluated by a joint team of government representatives from NSSL and the ROC over a nearly two year period. The evaluation teams focused on estimate quality, the impact of reduced sensitivity due to the transmit power division, and differential reflectivity calibration.
For a report on the results of the sensitivity evaluation, see the conference paper at this link:

http://ams.confex.com/ams/91Annual/webprogram/Manuscript/Paper183654/Sensitivity_Operational_Wx_Radars_Ice_27thIIPS_Jan2011_compact.pdf

For a report on the engineering evaluation led by the ROC see the conference paper at this link:

http://ams.confex.com/ams/91Annual/webprogram/Manuscript/Paper183657/IIPS27_379_DualPol_Validation_ExtAbstract_final_compact.pdf

The ROC also led an operational assessment of the benefits resulting from the WSR-88D polarimetric upgrade. This exercise involved members from field operations of the various NEXRAD agencies, and focused on possible impacts due to the sensitivity loss as well as benefits. The exercise concluded that significant operational benefits were achieved in precipitation estimation and winter weather forecasting. For a report see the conference paper at this link:
http://ams.confex.com/ams/35Radar/webprogram/Manuscript/Paper191334/AMS%20Paper%20on%20Ops%20Assessment%2012%20Sep%202011.pdf

Polarimetric Meteorological Radar Technical Challenges

Technical challenges remaining for an operational polarimetric radar continue to be related to estimate quality issues arising from several sources. Much work remains to be done in clutter filtering as the current operational approaches negatively impact the quality of the polarimetric variables, especially in weak signal regions. Differential reflectivity calibration, absent the ability to vertically point, remains a challenge. One aspect of this is the calibration verification process. Confirming that system bias can be determined to an accuracy of 0.1 dB or less is no small feat. The NEXRAD community has employed several methods in an attempt to verify this performance including analysis of reflectivity – differential reflectivity scatterplots in light precipitation and observation of differential reflectivity values in dry snow. The ROC is also pursuing the so-called “cross polarization power” method developed at the National Center for Atmospheric Research. For a current summary of this approach, see the paper at the link below:

http://ams.confex.com/ams/35Radar/webprogram/Manuscript/Paper191977/ZDRradar11.pdf

Other system challenges relate to maintaining calibration state, and accurately monitoring system noise. There are also a number of potential techniques to improve system sensitivity. These are surveyed in the conference paper at the link below:

http://ams.confex.com/ams/35Radar/webprogram/Manuscript/Paper192009/NEXRAD_DQ_Future_35th_Radar_Sept2011.pdf

SUMMARY OF POLARIMETRIC RESEARCH PRESENTED AT THE AMERICAN METEOROLOGICAL SOCIETY'S 35TH CONFERENCE ON RADAR METEOROLOGY, SEPTEMBER 26 – 30, 2011, PITTSBURGH, PA.

Conference Summary

Probably the best way to assess the state of any technology is to review the most current conference held in the field. For meteorological radar, this is the American Meteorology Society's Conference on Radar. This section reviews relevant papers presented at the AMS 35th Conference on Radar Meteorology, held in Pittsburgh PA, this past September.
Note that the conference program, including uploaded papers and posters along with recorded presentations is available at the following link:

http://ams.confex.com/ams/35Radar/webprogram/35RADAR.html

The 35th Radar Conference featured nineteen sessions, all focused on some aspects of meteorological radar. Some notable session topics relevant to the WSR-88D program were: Severe weather and mesoscale meteorology, Precipitation and cloud microphysics, Tropical cyclone studies, Results from VORTEX-II, Model validation using radar measurements, Spaceborne cloud and precipitation radars, Polarimetric radar applications, Tropical studies using radar, Technology and advanced applications, Assimilation of radar data, Precipitation and hydrologic applications, Winter storm studies using radar, Precipitation estimation and hydrological applications,
Prof. Chandrasekar of Colorado State University delivered the keynote address for the opening of the Technology and Advanced Applications session. Prof. Chandra focused on radar calibration and presented a clear statement of the challenges presented by polarimetric radar calibration.

National Weather Service WSR-88D Dual Polarization Upgrade Session

The conference committee included both oral presentation and poster sessions on "National Weather Service WSR-88D dual polarization upgrade". There were several presentations by members of the US Government, academia, and industry. A representative of the Radar Operations Center presented a talk on the WSR-88D dual polarization project that included a report on the recent Operational Assessment.

The WSR-88D dual polarization upgrade poster session included two posters:

"Counteracting Dropout Effects of Network Radar Replacements", Jörg E. E. Seltmann, German Weather Service, Hohenpeissenberg, Germany; and P. Lang and "Impacts and mitigation of ground clutter on S-band dual-polarimetric radar data", Scott M. Ellis, NCAR, Boulder, CO; and J. Hubbert, M. Dixon, and G. Meymaris

Dr. Seltmann presented the status of their current deployment of new dual polarization radars built by Enterprise Electronics Corporation. The focus of his poster was the DWD's process of installing a temporary radar to provide coverage during the extended construction and testing of the new radars.

While this paper is not specifically about the US radar network, it does provide valuable insight into the issues surrounding an operational radar network upgrade.

The work presented by Dr. Ellis at NCAR is significant as it documents the extensive data collection and simulation work done by NCAR on the effects of clutter on dual polarization variables. This work positions them to make significant contributions in our planned task to improve dual polarization data quality.

The oral sessions on the WSR-88D dual polarization included the following talks:

“Implementation of a Hydrometeor Classification Algorithm for consumer-oriented dual-polarization radar products”, Chris Porter, Weather Decision Technologies, Inc., Norman, OK; and B. C. Baranowski, W. Ladwig, B. Clarke, and B. Shaw

“Zdr calibration and simultaneous horizontal and vertical polarization transmit radars”, J.C. Hubbert, NCAR, Boulder, CO; and M. Dixon, V. Chandrasekar, D. A. Brunkow, P. C. Kennedy, R. L. Ice, and D. Saxion

“An Operational Assessment of Pre-Deployment Dual Polarization WSR-88D Radar Data”, Stephen B. Cocks, Radar Operations Center, Norman, OK; and P. T. Schlatter and J. B. Boettcher
“Combining the Coherency Based Detection and the 2D Despeckling to Improve Signal Detection in Dual-polarization Weather Radars”, Igor R. Ivic, CIMMS/Univ. of Oklahoma, Norman, OK; and V. Melnikov

As noted, the only presentation covering the current WSR-88D polarimetric upgrade by a government representative was the one by LtCol Cocks. Two of the other talks were also noteworthy. Dr. Hubbert, representing NCAR, provided a very clear and understandable explanation of the challenges of ZDR calibration and explained the cross polarization power method very concisely. Dr. Ivic, representing OU/CIMMS/NSSL, provided a very good overview of some sensitivity enhancement methods the ROC is considering for implementation in a future software release.

Polarimetric Radar Applications

Some interesting and relevant poster presentations from the Polarimetric Radar Applications sessions (oral and poster) are listed here.

“Sampling issues in using raindrop disdrometer observations to determine radar Zdr - Z relationships”, Paul Smith, South Dakota School of Mines and Technology, Rapid City, SD

“Sensitivity of C-band Polarimetric Radar-based Drop Size Distribution Measurements to Maximum Diameter Assumptions”, University of Alabama, Huntsville, AL; and W. A. Petersen

“Statistical quality of spectral polarimetric variables for weather radar”, Tianyou Yu, Univ. of Oklahoma, Norman, OK; and X. Xiao and Y. Wang

“Onsite radome performance verification”, Michael Frech, DWD, Hohenpeissenberg, Germany; and B. Lange, T. C. Mammen, J. E. E. Seltmann, C. Morehead, and J. Rowan

“The French operational dual-polarization processing chain”, Abdel-Amin Boumahmoud, Météo France, Toulouse, France; and B. Fradon, P. Roquain, L. Perier, and P. Tabary

“Polarimetric signatures of precipitating clouds as a proxy for vertical velocity and possible use in precipitation nowcasting”, Renzo Bechini, ARPA Piemonte, Torino, Italy; and V. Chandrasekar

“Monitoring polarimetric weather radar calibration”, Lesya Borowska, NOAA/NSSL, Norman, OK; and D. Zrnic

“Polarimetric properties of ice cloud particles”, Valery Melnikov, University of Oklahoma/CIMMS, Norman, OK

“Spatial variability of rain drop characteristic sizes as estimated from X-band polarimetric radar”, Sergey Y. Matrosov, CIRES/University of Colorado and NOAA/ESRL, Boulder, CO

“First experiences of operational use of a dual-polarization weather radar in Finland”, Ljubov Joanna Nevvonen, Finnish Meteorological Institute, Helsinki, Finland; and E. Saltikoff

“Onsite dualpol antenna performance verification”, Michael Frech, DWD, Hohenpeissenberg, Germany; and B. Lange, T. Mammen, J. Seltmann, C. Morehead, and J. Rowan

“Degree of Polarization at Simultaneous Transmit. Theoretical Aspects”, Michele Galletti, NOAA/NSSL, Norman, OK; and D. S. Zrnic and V. Melnikov

“Value of a Dual-Polarized Gap-Filling Radar in Support of Southern California Post-fire Debris-Flow Warnings”, David P. Jorgensen, NOAA/NSSL, Norman, OK; and M. N. Hanshaw, K. M. Schmidt, J. L. Laber, D. M. Staley, J. W. Kean, and P. J. Restrepo

“Calibration of Differential Reflectivity on the X-band weather radar”, Shi Zhao, Chengdu University of Information Technology, Chengdu, Sichuan, China; and H. Jianxin, L. Xuehua, and W. Xu

“Time series of microphysical structure of a thundercloud examined with hydrometeor classification method for X-band polarimetric radar”, Takeharu Kouketsu, Nagoya University, Nagoya, Japan; and H. Uyeda and T. Ohigashi

“An overview of several polarimetric signatures within supercells as seen by a mobile, X-band, polarimetric Doppler radar”, Jeffrey C. Snyder, Univ. of Oklahoma, Norman, OK; and H. Bluestein, Y. Jung, V. Venkatesh, and S. J. Frasier

“A probability based sea clutter suppression method for polarimetric weather radar systems”, Ronald Hannesen, Selex SI GmbH, Neuss, Germany; and A. Weipert

“Lightning initiation forecasting: an operational dual-polarimetric radar technique”, Crystal J. Woodard, University of Alabama, Huntsville, AL; and L. D. Carey, W. A. Petersen, and W. P. Roeder

“Retrieval of microphysical properties for the mixture of rain and hail using Doppler spectral analysis and genetic algorithm”, Yadong Wang, CIMMS/Univ. of Oklahoma, Norman, OK; and T. Y. Yu and X. Xiao

“Numerical Experiments with a Variational Scheme for Attenuation-Correction for X-band Radar”, Leonid Tolstoy, Colorado State University, Fort Collins, CO; and V. N. Bringi and R. J. Hogan

“Characteristics of Chaff Echo Observed by NIMR X-band Dual Polarization Radar”, Kyung-Yeub Nam, National Institute Meteorological Research / Korea Meteorological Administration, Seoul, South Korea; and K. H. Chang and Y. J. Choi

“Accuracy of dual-polarimetric parameters from a commercially built operational S-band dual-polarization radar”, Soohyun Kwon, Kyungpook National University, Deagu, South Korea; and G. Lee, Y. H. Cho, Y. A. Oh, and C. K. Lee

“Rain estimation using X-band dual-polarimetric radar by correcting attenuation”, Young-a Oh, Kyungpook National University, Deagu, South Korea; and Y. H. Cho, K. Y. Nam, and G. Lee

“The use of polarimetric radar data to characterize drop size distribution regimes in moderate to heavy convective rain”, Patrick C. Kennedy, Colorado State Univ., Ft. Collins, CO; and V. Chandrasekar and S. A. Rutledge

“A simple-but-realistic fuzzy logic hydrometeor classification scheme for the French X, C and S-band polarimetric radars”, Hassan Al-Sakka, Météo France, Toulouse, France; and F. Kabeche, J. Figueras i Ventura, B. Fradon, A. A. Boumahmoud, and P. Tabary

“A Study of Quantitative Precipitation Estimation Methods Based on S-band Dual-Polarization Doppler Radar”, Wenjian Zhu, National Meteorological Center, Nanjing, Jiangsu, China; and K. Zhao, B. J. D. Jou, and P. Zhang

“Verification of ensemble Kalman filter analyses of a convective storm with a one- and a two-moment bulk microphysics scheme using polarimetric radar”, Youngsun Jung, CAPS/Univ. of Oklahoma, Norman, OK; and M. Xue and M. Tong

“Analysis of dual polarization radar observations in the Helsinki test bed”, Reino Keranen, Vaisala, Oyj, Helsinki, Finland; and V. Chandrasekar. Note: this paper is mistitled in the program. The proper title is “Enhanced detection capability for dual polarization weather radar”

“Polarimetric attenuation correction and rainfall estimation for heavy rain events at C band”, Ji-Young Gu, Pukyong National University, Busan, South Korea; and A. Ryzhkov, D. I. Lee, B. J. Wolf, and R. Palmer

“Operational polarimetric variables calibration at Météo France: where do we stand?”, Jordi Figueras I Ventura, Météo France, Toulouse, France; and G. Pagan, A. A. Boumahmoud, and P. Tabary

“Quantitative precipitation nowcasting using specific differential phase”, Evan Ruzanski, Vaisala, Inc., Louisville, CO; and V. Chandrasekar

“On the correction of attenuation with simultaneous transmit dual-polarization radars”, Scott M. Ellis, NCAR, Boulder, CO; and J. Hubbert and M. Steiner

“On the use of a polarimetric X-band weather radar for volcanic ash clouds monitoring”, Gianfranco Vulpiani, Dipartimento di Protezione Civile, Roma, Italy; and M. Montopoli Sr., E. Picciotti, and F. S. Marzano

“Estimation of noise induced variances in the dual-pol moments using simple parametric model of the recorded signal”, Sergey Panov, Vaisala Inc., Wesford, MA

“Mesoscale boundaries observed by SPOL in sowmex/timrex”, Ben Jong-Dao Jou, National Taiwan University, Taipei, Taiwan; and R. G. Hsiu

Technology and Advanced Applications

Some interesting and relevant poster presentations from the Technology and Advanced Applications sessions (oral and poster) are listed here:

“Recent Advances in Weather Radar Calibration”, V. Chandrasekar, Colorado State University, Fort Collins; and N. Bharadwaj, D. Brunkow, J. George, J. Gerlach, J. Hardin, J. Hubbert, R. L. Ice, F. Junyent, J. Lee, K. V. Mishra, D. Saxion, P. Smith, M. Vega, and B. Walker.

“Exploring impacts of radar scan time on NWS warning decision making”, Pamela L. Heinselman, NOAA/NSSL, Norman, OK; and D. LaDue and H. Lazrus

“Spectral processing and ground clutter mitigation for dual polarization staggered PRT signals in Doppler weather radars”, David A. Warde, CIMMS/Univ. of Oklahoma, Norman, OK; and S. M. Torres and B. Gallardo

“Fast Calibration of Weather Radar Systems for Multi Polarisation Radar Measurements”, Jens Reimann, DLR, Oberpfaffenhofen-Wessling, Germany; and M. Hagen

“Sensitivity enhancement system for pulse compression weather radar”, Cuong M. Nguyen, Colorado State University, Fort Collins, CO; and V. Chandrasekar, K. V. Mishra, and J. George

“Fine structures of refractivity in the boundary layer reveled with a polarimetric WSR-88D”, Valery Melnikov, University of Oklahoma/CIMMS, Norman, OK; and R. J. Doviak, D. S. Zrnic, and D. J. Stensrud

“Weather Radar Calibration and Testing using the Moon as Reference Target”, Frank Gekat, Selex Systems Integration GmbH, Neuss, Germany; and P. Goelz and R. Hannesen

“Spectrum-time estimation and processing (STEP) algorithm for improving weather radar data quality”, Qing Cao, University of Oklahoma, Norman, OK; and G. Zhang, R. D. Palmer, R. M. May, R. Stafford, and M. Knight

“Solid-state weather radar which reached the practical use stage”, Masakazu Wada, Toshiba Corp., Tokyo, Japan; and H. Ueda

“Modeling radar power and phase antenna patterns and the evaluation of dual-polarization antenna performance”, John Hubbert, NCAR, Boulder, CO; and R. A. Rilling

“Adaptation of hybrid spectrum width estimator to staggered PRT for WSR-88D”, Gregory Meymaris, NCAR, Boulder, CO; and J. Hubbert

“FRONT: The Front Range Observational Network Testbed”, J. C. Hubbert, NCAR, Boulder, CO; and P. C. Kennedy, V. Chandrasekar, S. A. Rutledge, W. C. Lee, V. N. Bringi, J. W. Wilson, D. A. Brunkow, M. Dixon, T. Weckwerth, J. George, E. Loew, J. VanAndel, A. Phinney, B. Bowie, R. A. Rilling, and S. M. Ellis

“A fresh look at the range weighting function for modern weather radars”, Sebastian M. Torres, CIMMS/Univ. of Oklahoma, Norman, OK; and C. D. Curtis

Other Notable Papers on Dual Polarization

“Quantification of errors in polarimetric radar variables simulated from bulk microphysics parameterizations”, Matthew R. Kumjian, CIMMS/Univ. of Oklahoma and NOAA/NSSL, Norman, OK ; and A. V. Ryzhkov, S. M. Ganson, and A. Khain. This oral session paper provides intriguing insight into expected values of Z, ZDR, KDP and RHO based on analysis of simulated drop size distributions for several different models.

"Supercell polarimetric signatures at X-band: Data from VORTEX2", Christopher M. Schwarz, University of Oklahoma, Norman, OK; and D. W. Burgess. This poster "…Data obtained from three supercell thunderstorms during the Verification of the Origins of Rotation in Tornadoes EXperiment, Part 2 (VORTEX2) by the NOAA (NSSL) X-band Polarized (NOXP) mobile weather radar are investigated. The 5 June and 7 June 2009 supercells and the 10 May 2010 supercell are analyzed in an attempt to quantify previously noted C- (5 cm wavelength) and S-band (10 cm wavelength) dual-polarimetric signatures such as the tornadic debris signature (TDS), the updraft signature, the hail signature, the ZDR arc, ZDR and KDP columns, Rhv and ZDR rings, as seen at X-band (3-cm wavelength)…" Although the extended abstract is about X band data, the basic ideas of how to interpret dual polarization variables are quite useful and provide insights into the things the data quality team has been seeing in the production 10 cm data.

"Comparison of Drop Size Distribution Parameter (D0) and Rain Rate from S-Band Dual-Polarized Ground Radar, TRMM-Precipitation Radar (PR) and Combined PR/TMI: Two events from Kwajalein Atoll", V.N. Bringi, Colorado State University, Fort Collins, CO; and G. J. Huang, S. J. Munchak, C. Kummerow, D. A. Marks, and D. B. Wolff. This oral presentation compared computed DSDs from the Kwajalein Atoll radar (KPOL) and the orbiting TRMM satellite. It provides some insight into critical dual polarization calibration methods used at KPOL. Their observed good agreement between DSDs and rain rates observed by both radars provide some confidence in the dual polarization calibration at KPOL since the models employ the dual pol variables. This was significant even though the ZDR calibration at KPOL was essentially "retroactive", based on co-located disdrometer observations. This paper serves as a good tutorial on methods and especially drives home the challenges of dual polarization calibration.