RICO S-PolKa Radar Data Availability and QA

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With extensive contributions from

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All Results are Preliminary

RICO Data Workshop, Boulder, CO 27-Jun-2005

A Lot to Cover:

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- Information availability
- Data set description
  - Radar
  - Antenna camera images
- Processing status
- Data availability
- Quality Assurance Issues

Issues to Resolve

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- Level of data quality required
- Priority time periods
- Parameters for inclusion in final data
- Data distribution mechanism
- Ongoing updates and feedback
  - S-PolKa RICO report
  - Bugzilla for S-PolKa?
  - Wiki?

On-Line Resources

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- S-PolKa-band Project Report
  - http://www.atd.ucar.edu/rtf/projects/rico2004/spol
  - very much under construction!
  - Intended to be the repository of all information
- Requesting Data
  - http://www.atd.ucar.edu/rdp/mss_retrieval
  - http://www.joss.ucar.edu
- JOSS on-line info
  - http://www.joss.ucar.edu

About S-PolKa in RICO

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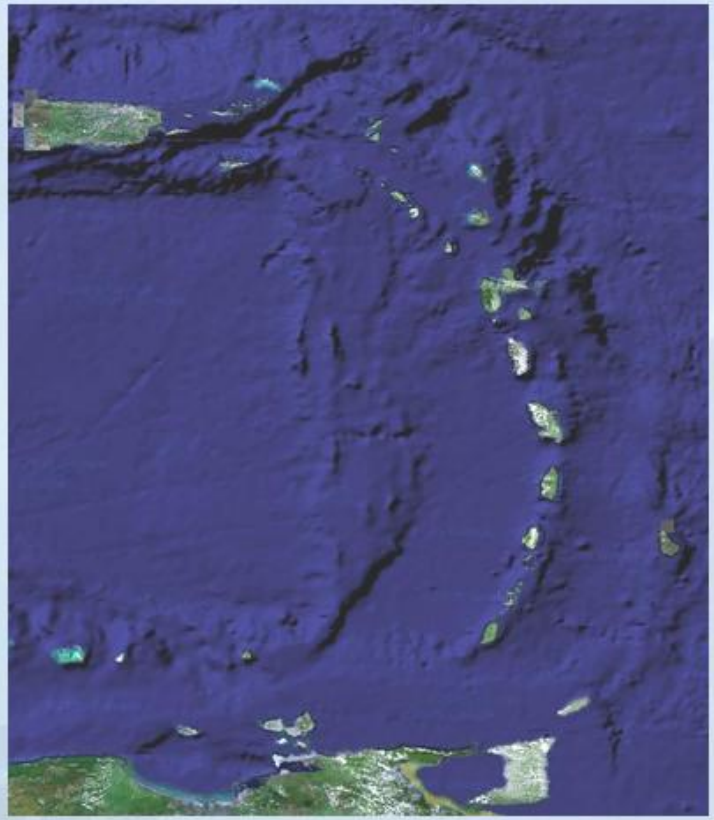
- The location
- The Site
- View from the radar
- Clutter
- Why use S and K bands?



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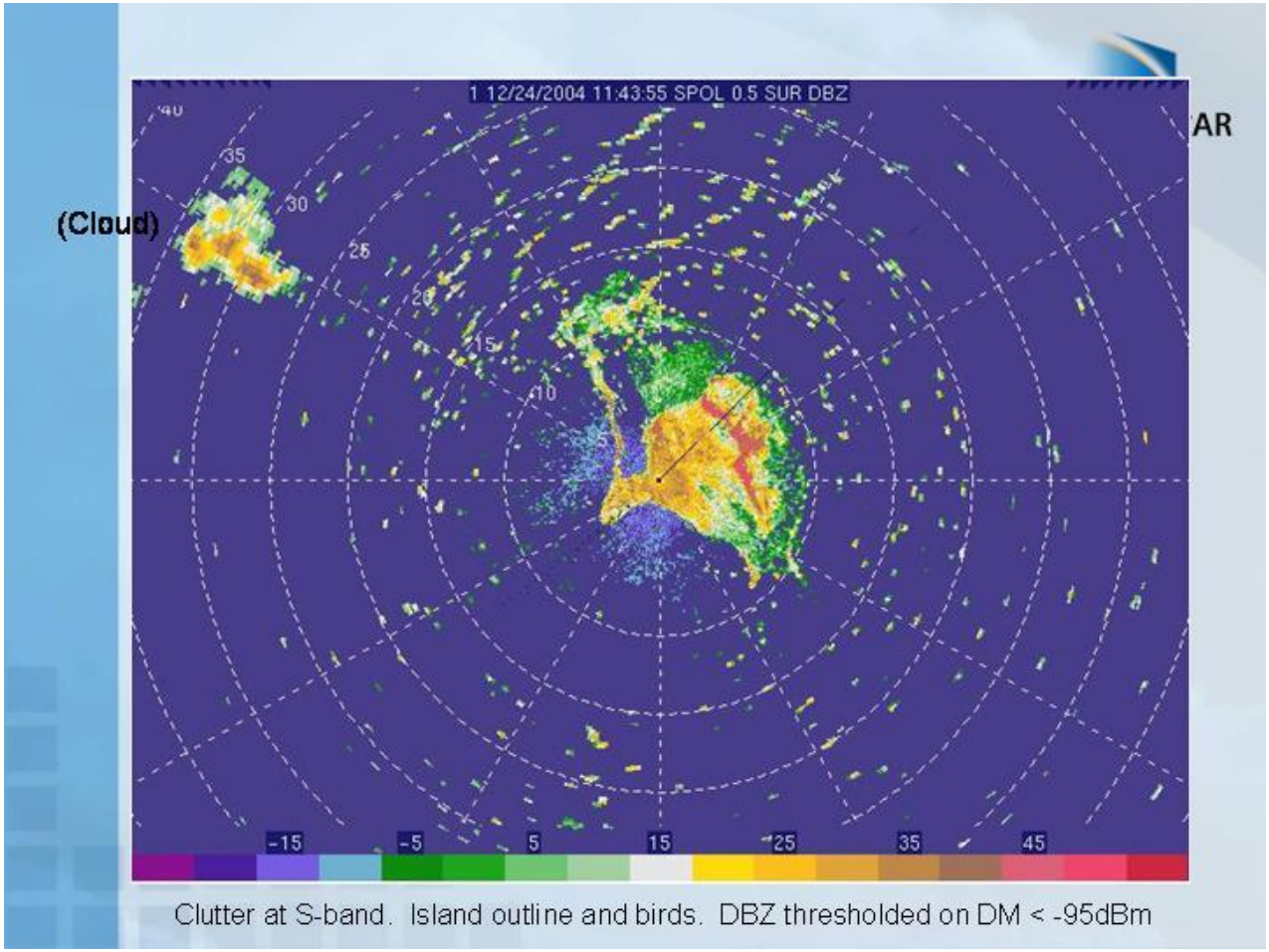
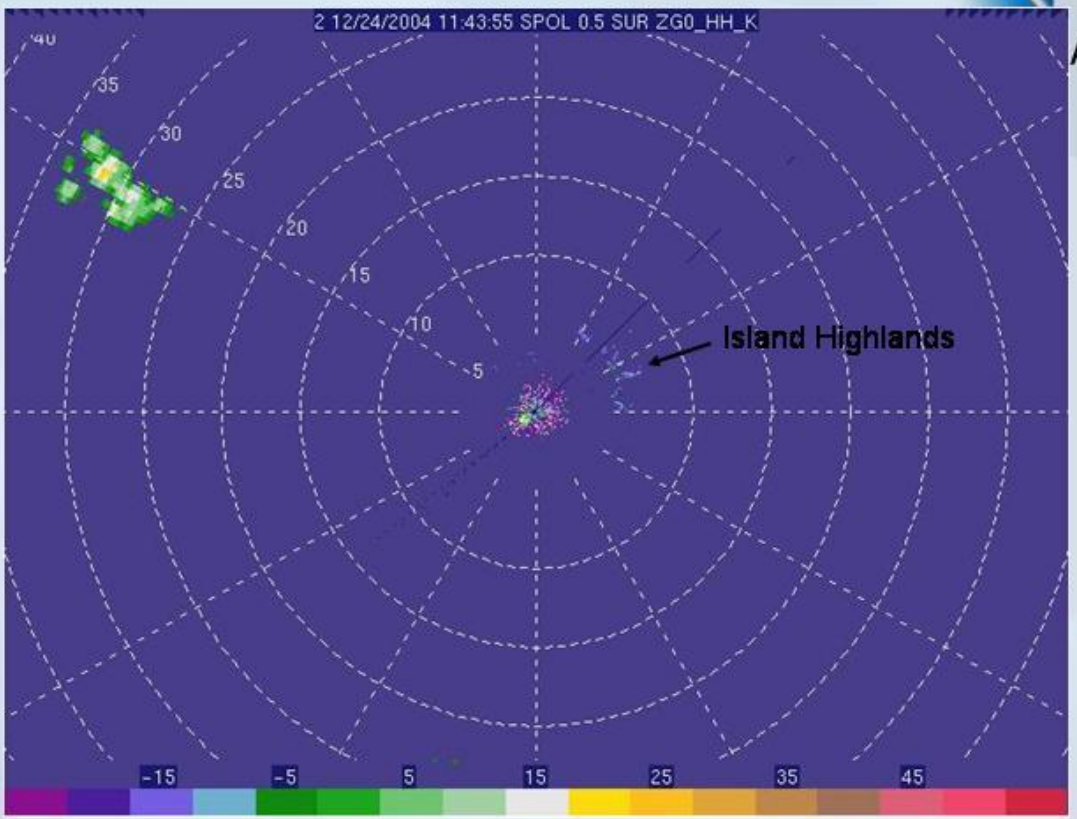
Below Sea-level!

http://www.atd.ucar.edu/rtf/projects/rico2004/spol/photos/Panorama/Spol_RICO_pano.html



Clutter at S-band. Island outline and birds. DBZ thresholded on DM < -95dBm



AR

Clutter at Ka. ZG0_HH_K thresholded on P_HH_K < -110 dBm

Period of Operations

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- 24-Nov-2004 thru 25-Jan-2005
  - Earliest collections were incomplete
- 24/7 ops targeted for S-band
- On-demand ops for Ka, with consideration for magnetron lifetime
- Approximately 1/3 ops with Ka
- Actual mileage did vary! (see operations matrix)

Some Metrics

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- Over 1300 hours of operation
- ~25 measured/derived parameters
  - See parameter list
- Raw data set size of 1.7 TBytes
- Processed size of about the same (1.8TB)
- 1.45 GB/hour with Ka (all variables)
- 1.2 GB/hour, S-band only
- Able to create re-processed data at 10 to 12 times realtime (4 to 6 24-hr days to reprocess)
- Antenna Camera: 700 hours, 5.5 million images, 120 GB

S-PolKa Parameters

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DBZ
CDBZ
DL
DM
DX
DY
LDR
LVDR
NCP

PHIDP
RHOHV
SW
VR
ZDR

AIQ
NIQ

NCP_HH_K
P_HH_K
P_VV_K
PHO_HV_K
SW_HH_K
TH_VH_K
V_HH_K
ZDR_VH_K
ZG0_HH_K
Z_HH_K

Why Ka?

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- Sensitive to small cloud drops
- Insensitive (mostly?) to Bragg scattering
- Potential for new insights using Zdr (and other polarimetric variables) at Ka
- Insensitive to clutter from sidelobes
  - $\lambda^{3.9}$ dependence (Kropfli and Kelly, 1998)
  - Would greatly limit sea clutter (but siting made this unnecessary)
- Potential for liquid water measurement through S/Ka differential attenuation
- Excellent signal statistics

Generic Ka Issues

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- Highly attenuated frequency
- Subject to Mie scattering
- Subject to differential Mie scattering
- Electronics are somewhat unstable (temperature sensitivity, frequency drift)

RICO Data Quality Concerns

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- Ka on S-Pol is a new system for NCAR
- Ka received little testing in RICO configuration prior to 24-Nov-2004
- Incompletely characterized system
- High-frequency systems can be fussy!
- S-band had taken a beating coming back from Mexico (power meter, coupler, etc.)
- Unfamiliar with utility of Ka for measurement of tropical clouds
- Much new software, both for radar processors and post-production

S-Pol Radar QC Procedures

Engineering Checks

i. Inspect all waveguide connections; scanning for leakages

ii. Inspect antenna assembly; check feedhorn position

iii. Measurement of transmitted power

iv. Test signals to determine waveguide losses, system/receiver gains

v. Tuning receivers and transmitters

vi. Verify waveforms

vii. Review radar processor performance

viii. Comparison with past histories

ix. etc.

Special Data Set Collection

i. Antenna pattern measurements (between projects)

ii. Feedhorn/sphere calibrations (done rarely; logistical issues)

iii. Solar scans and calibrations (direct verification of received power/gain)

iv. Solar alignment checks (for antenna pointing (azim/elev)

v. Clutter scans (e.g. range/gate alignment issues)

vi. Vertical pointing scans (zdr bias estimate)

vii. Low-level scans (beam blockage issues)

viii. Analysis of candidate data sets for self-consistent calibration (PHI-cal)

Data Monitoring

i. Constant review of data recording reliability

ii. Review of antenna scanning

iii. Monitoring of test pulse signals

iv. Monitoring of background noise power

v. Monitoring of parameters for generally correct signatures

vi. Review of clutter patterns for unexpected azimuth shifts

vii. Review of changes to processing software

Known Hardware Problems

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- Ka Magnetron failure prior to 15-Dec-2004
- Ka coax failure
- Ka cal drift with temperature changes
- S-band power meter calibration issue
- S-band processor dropouts
- Non-optimal Ka design for Zdr
  - Waveguide loss
  - Separate H and V receivers

Data Quality Concerns

NCAR

- Radar absolute calibration (really, 4 radars: Ka HH and VV; S HH, VV)
- Exact beam alignment
- Exact gate alignment
- Exactly synchronous sampling (related to beam alignment)
- Short- and Long-term systems stability
- Guarding against dropped data and meta data
- Full characterization of systems

Specific Issues

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- S-band calibration
- S-band Zdr bias
- Ka noise power stability (background checks)
- Ka noise power subtraction
- Ka calibration: relation to S-band
- Ka attenuation and beam blockage
- Preliminary systems sensitivities
- Ka/S beam alignment
- Ka HH/VV gate alignment

S-Band Calibration

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- Systems measurement (table available)
- Solar calibration
- Self-consistent calibration (Ellis' "PHICal")

- Result: +1.4 dB correction to S-band DBZ
  - very good level of confidence
  - Not yet applied to semi-processed data

NCAR

1994	2809											44.80	44.40	Cleave y measured
9-Apr-96	2813					-115.70	-115.40							FL1
27-Dec-96	2745					-116.00	-115.50							Bad Lake
18-Apr-96	2809	56.40	55.40	-36.00	-35.60	-115.20	-115.40							CASES. New Preselectors.
22-Oct-97	2809	56.30	55.40	-35.90	-35.70									Diode power meters now used
17-Mar-97	2809											45.00	45.60	Ham at Mesa
12-Feb-98	2809					-115.20	-114.80							Mid chdetermined bandwidth = 804 kHz 4/23/98
20-Feb-98	2809							45.20	45.70	45.71	45.93			
12-Mar-98	2809							45.60	45.70	45.11	45.93			Rx based on Penticton data @ 2800 mhz or Palehua @ 3395 and 4995 mhz.
19-Mar-98	2809											45.00	44.80	~ 1 foot of wet snow on ground.
26-Mar-98	2809							45.80	45.90	45.31	45.13			1842Z & 2132Z. Jon says he hear ~ 1/4 dB better peak than previous
22-Apr-98	2809											45.70	44.30	measurement.
22-Apr-98	2809							45.40	46.00	44.91	45.23			Best ever. Using Millichi's Range Averaging.
25-Apr-98	2809					-115.10	-114.80							Jon measures from processor.
29-Apr-98	2809							45.60	45.60	45.11	44.83			Odar power measures 0.2 d B more dbelly w/ hindsite correction.
1-May-98	2809							46.00	45.90	45.51	45.13			Odar power 0.2 d B more Hor, 0.1 dB more Ver w/ hindsite correction.
11-May-98	2809									45.61	45.43	45.10	45.20	Eldorado Mountain
14-May-98	2809							45.90	45.70	45.41	44.93			Lazer TR Lite (unknown loss) in Hor channel.
18-Jul-98	2809	56.70	57.32	-35.90	-35.60	-115.20	-114.50	46.03	46.05	45.51	45.30			1st cal in Florida for PREDICTS98
19-Jul-98	2809							46.12	46.14	45.60	45.39			2nd cal in Florida for PREDICTS98
20-Jul-98	2809							46.10	46.02	45.58	45.27			3rd cal in Florida for PREDICTS98
11-Aug-98	2809							46.12	46.14	45.60	45.39			4th cal in Florida for PREDICTS98
25-Sep-98	2809							46.05	46.12	45.53	45.37			5th cal in Florida for PREDICTS98
12-Jan-99	2809	56.80	57.10	-35.90	-35.55	-115.20	-114.50	45.90	46.03	45.38	45.28			1st cal in Brazil. Used Penticton flux values. Noise cal from Florida. 2040GMT
19-Jan-99	2809							46.09	46.14	45.57	45.39			2nd cal in Brazil. Done in morning at 1250GMT
27-Jan-99	2809							45.93	46.05	45.41	45.30			3rd cal in Brazil. Done in morning at 1330GMT
2-Feb-99	2809							45.89	46.08	45.37	45.38			4th cal in Brazil. Done in morning at 1240GMT
7-Sep-99	2786	57.00	57.30	-35.88	-35.32	-115.20	-115.00	45.11	45.18	44.88	45.22			1st cal in Italy. Done at 0730GMT, Noise cal from Italy 9/7/99. Used interpolation for flux value.
10-Sep-99	2786							45.27	45.43	45.04	45.47			Cal done in morning at 0800GMT. Az error +0.2, El error +0.7
10-Sep-99	2786							45.23	45.33	45.00	45.37			Cal done in afternoon at 1400GMT. Az error +0.1, El error -0.8
21-Sep-99	2786							45.10	45.22	44.87	45.25			Cal done in morning at 1040GMT. Az error +0.3, El error +0.5
21-Sep-99	2786							45.86	45.96	44.63	45.00			Cal done in afternoon at 1430GMT. Az error -0.2, El error -0.5
12-Oct-99	2786							45.02	45.02	44.79	45.05			Rx1 cal done after feed replacement. Taken at 1240GMT
14-Oct-99	2786							45.19	45.19	44.96	45.23			Second cal w/ hi new feed. Taken at 1243GMT
2-Nov-99	2786							45.83	45.63	44.60	44.67			Taken at 0500GMT. Some heavy cloud in area. AZ -0.2, El +0.9
7-Nov-99	2786							45.88	44.98	44.65	43.62			Last cal in Italy, done at 1130GMT. Az error +0.1, El error -0.1
13-May-00	2809	56.80	57.15	-35.85	-35.55	-115.20	-115.00	45.67	45.19	44.82	44.44			1st cal for STEPS. May have noise correction

PHI-Cal

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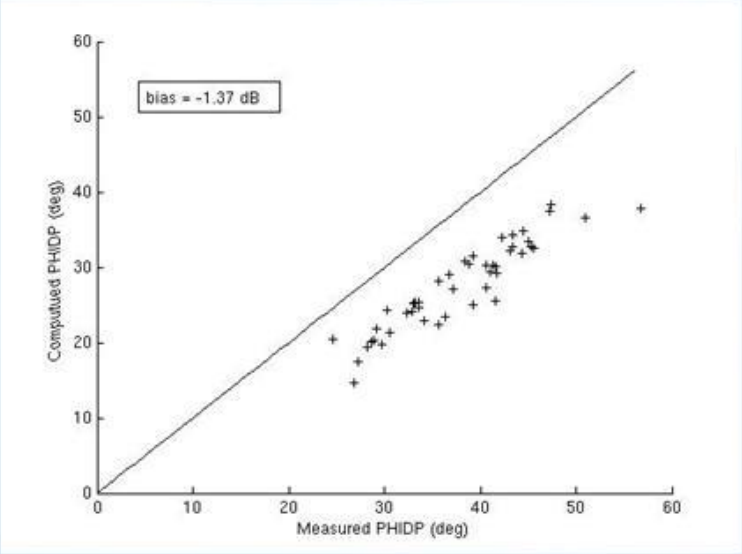

-- requires good study case(s) (only 2 for RICO)
-- requires good assumptions of droplet size distribution
-- requires calibrated Zdr

Zdr Bias

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- Zdr is residual difference between two large quantities ($Zdr = dBZ_{hh} - dBZ_{vv}$)
- Require accuracy of Zdr to < .1 dB
- dBZ_{hh} and dBZ_{vv} known only to ~.5 dB
- Both dBZ_{hh} and dBZ_{vv} are very stable at S-band (no wandering over time), even if absolute calibration is uncertain
- A bias can be added, if one can be determined.
- Require real-world targets with known Zdr characteristics

Targets for Zdr Bias Determination

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- Small raindrops/cloud at vertical incidence
  - Often available
  - Limited utility of shallow clouds due to radar T/R tube issues
- Bragg scattering
  - Very available
  - Somewhat large scatter in determinations
- Very small hydrometeors at non-vertical
  - Selection criteria can be very subjective
- Ground clutter (Hubbert & Bringi, 2003)
- Solar return (not used)

Zdr Bias Determinations

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Vertical Pointing	.2 dB	Clouds too shallow; T/R tube recovery issues
Bragg scattering	.2 to .5	Noisy determination
Small hydrometeors	n/a	(not done)
Ground Clutter	.37	Well behaved results, tight distribution

Result: add .37 dB to all raw S-band Zdr values

Ka Receiver Stability

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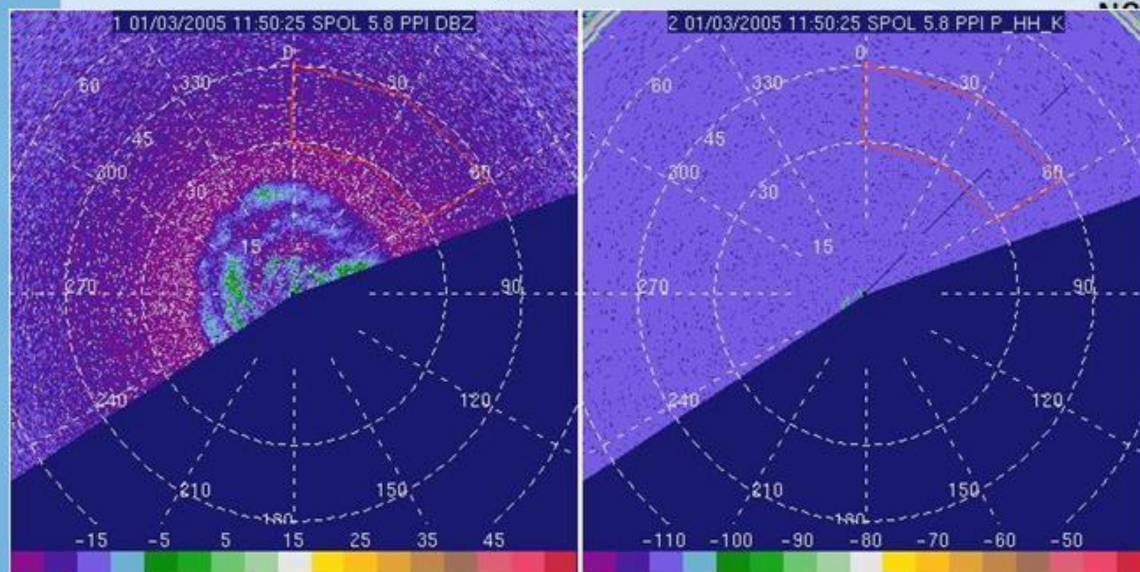
- V receiver and H receiver
- Long-term (gross) stability from noise studies
  - System noise should be fairly constant
  - Atmospheric noise should be fairly constant
  - Can't always tell which is which!
- Short-term from internal processor files

Ka background noise



(Ka prior to implementing noise subtraction)

```
-115.50
-114.50
-113.50 H
-112.50 HHHHHHHHHHHHHH
-111.50 HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH
-110.50 HHHHHHHHHHHHHHHHHHH
-109.50 H
-108.50
-107.50
```

P_HH_K
Mean = -111.4

500 similar determinations.

Project P_HH_K Noise Summary

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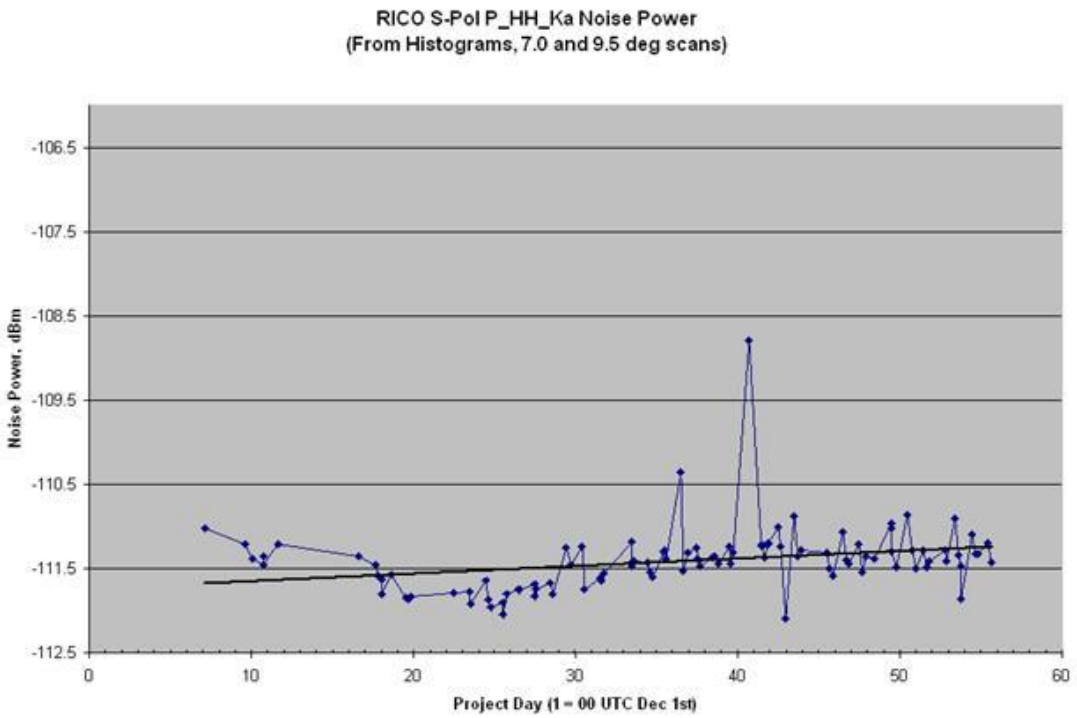
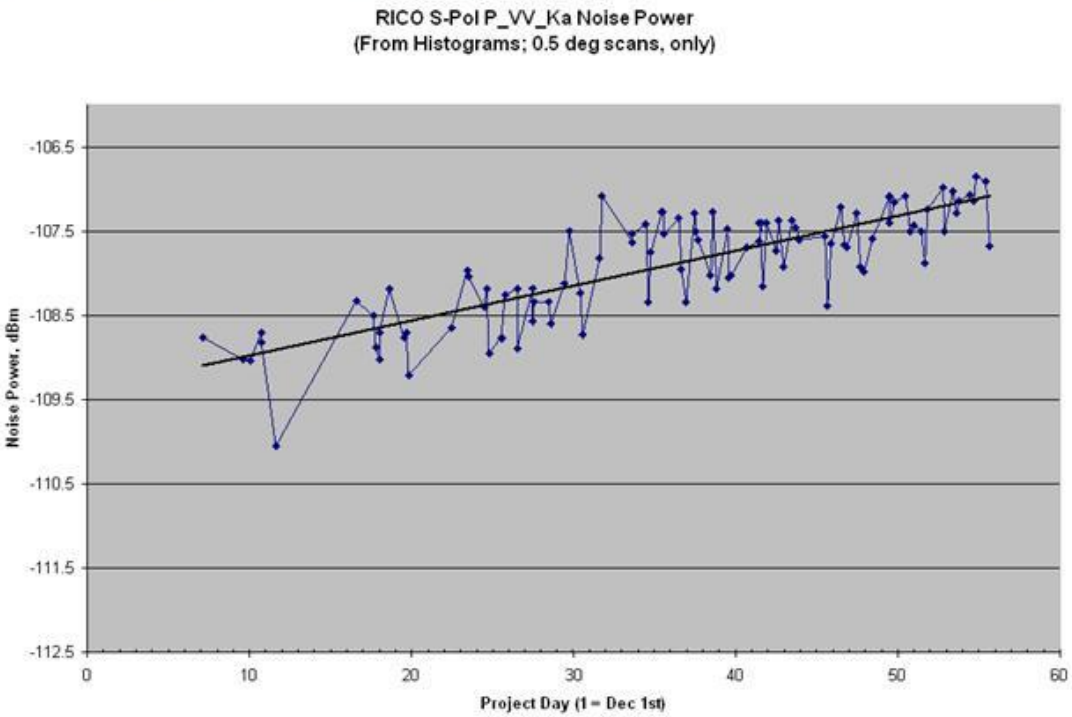


Project P_VV_K Noise Summary

NCAR



Need for accurate noise determination

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- Application of noise subtraction correction:

  $$M = S + N$$

- Impact on sensitivity vs range

Potential Noise Subtraction Errors

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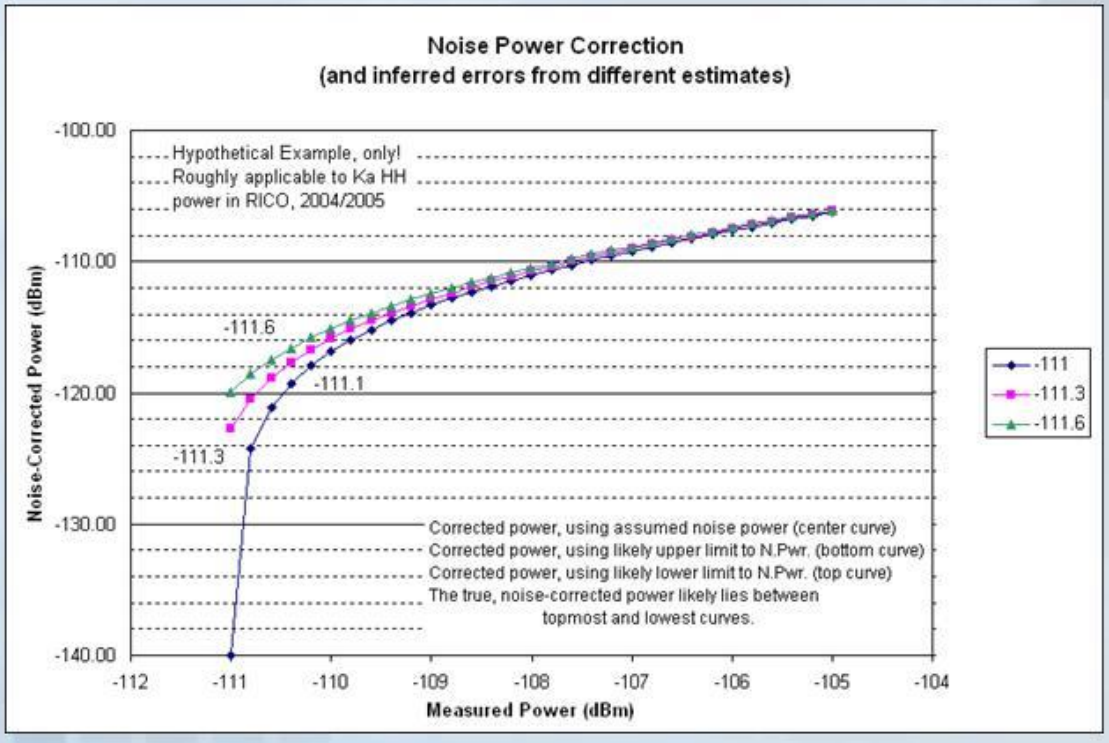

P_HH_K

Potential Noise Subtraction Errors

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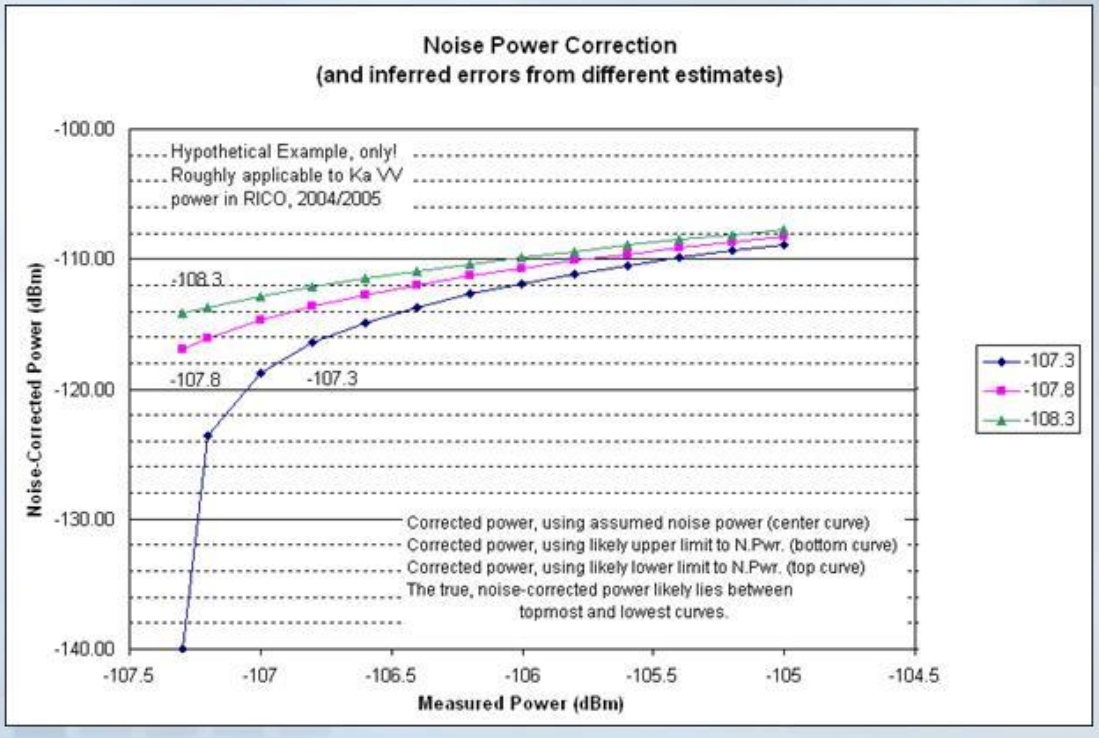

P_VV_K

Ka Calibration

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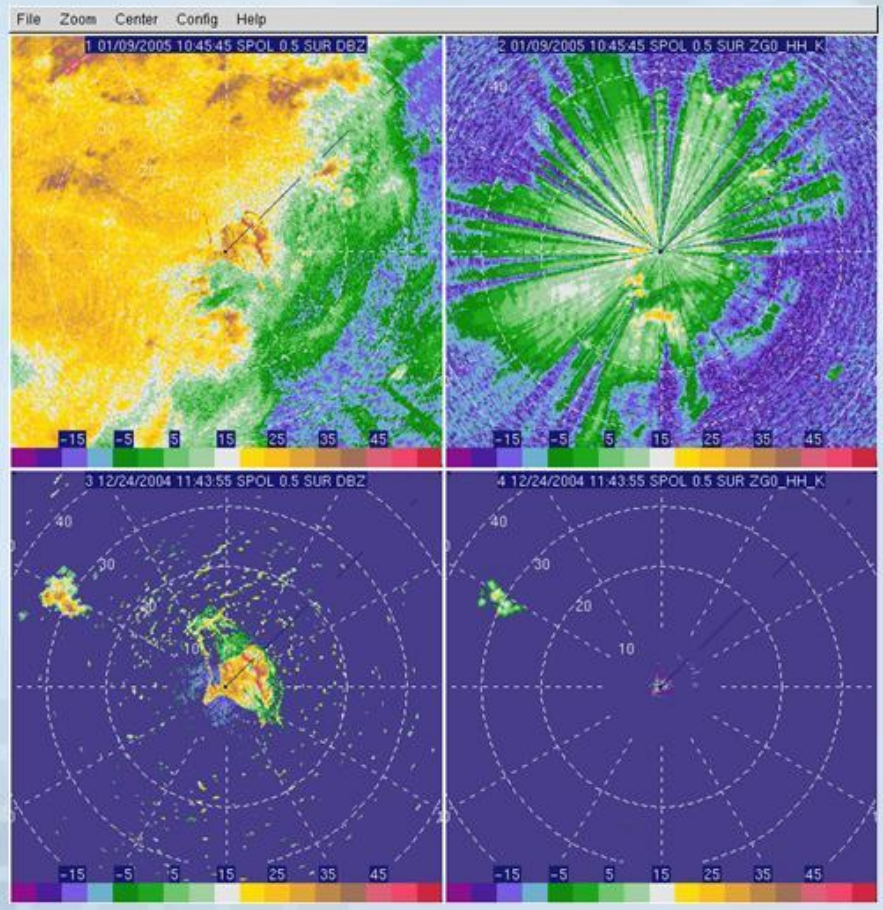
- **Which Ka parameter?**
  - ZG0_HH_K (adjusted for transmit-power)
  - Z_HH_K (uses static value of tx power)
- **Match to S-band: our only real option**
- **Real-world problems**
  - Ka beam blockage (partial power loss)
  - Ka attenuation by gas and hydrometeors
  - Bragg scattering
  - Changing Ka/S bias?


File Zoom Center Config Help
1 01/09/2005 10:45:45 SPOL 0.5 SUR DBZ
2 01/09/2005 10:45:45 SPOL 0.5 SUR ZG0_HH_K
3 12/24/2004 11:43:55 SPOL 0.5 SUR DBZ
4 12/24/2004 11:43:55 SPOL 0.5 SUR ZG0_HH_K
-15 -5 5 15 25 35 45
10 20 30 40

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Ka Z_HH Sensitivity

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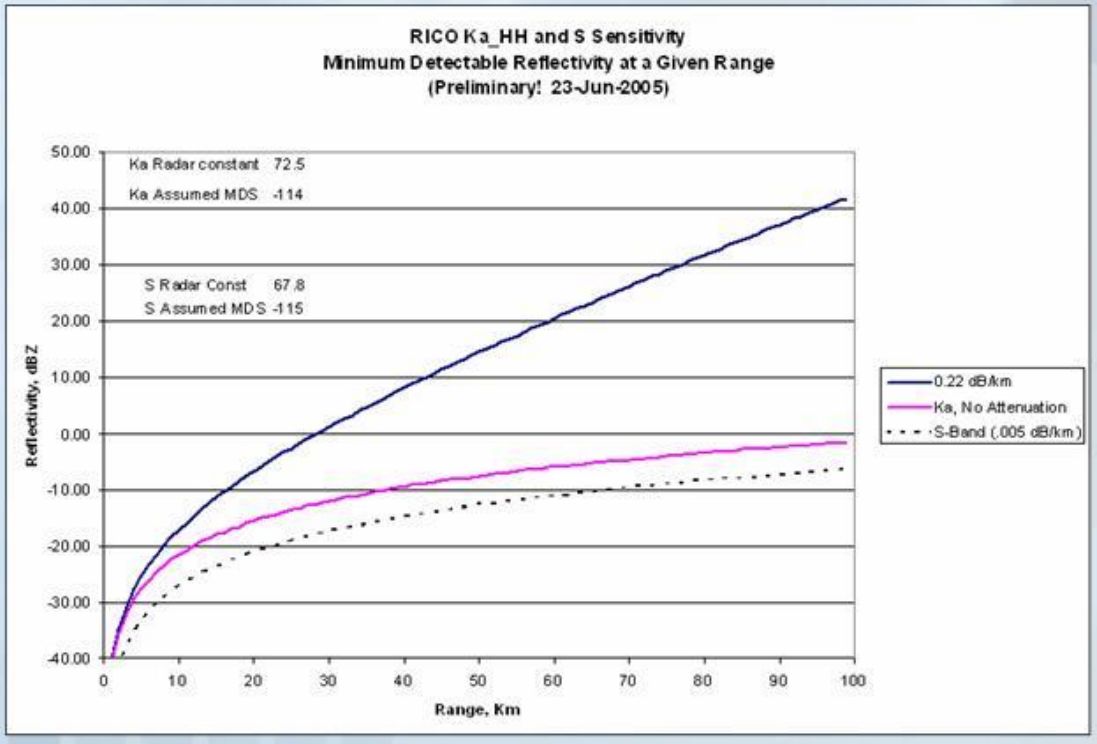
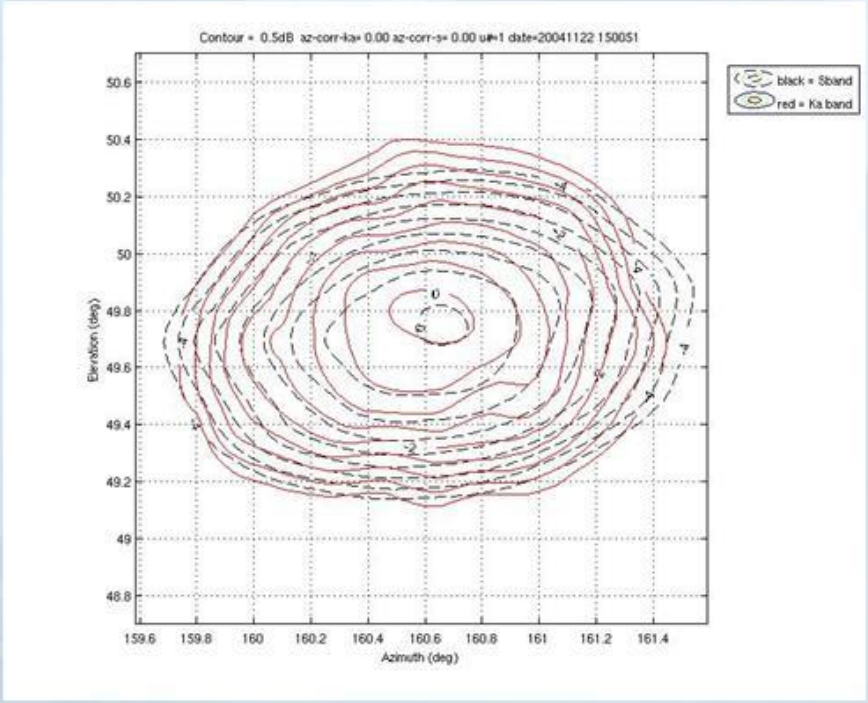


Ka/S Beam Alignment

NCAR



Gate Alignment

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- Checked by clutter and weather
- S-band HH matches S-band VV
- Ka HH matches S-band HH (with single gate adjustment)
- Ka VV does not match Ka HH!
  - About ½ gate off
  - Adjusted to about ¼ gate on 26-Dec
  - Affects Ka Zdr

Tower Comparison

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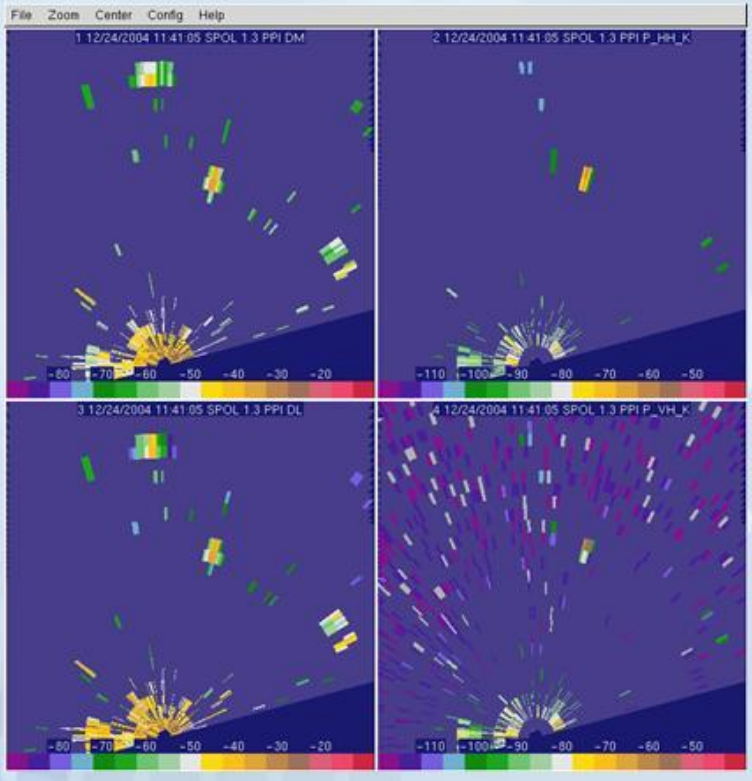

Shh and Khh Reflectivity Comparison, with Attenuation

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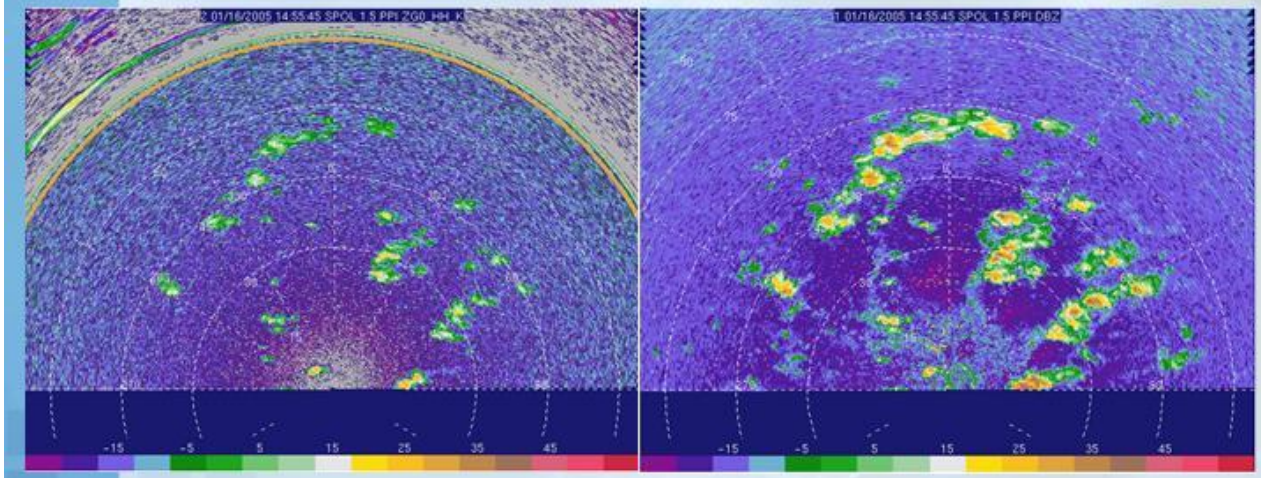
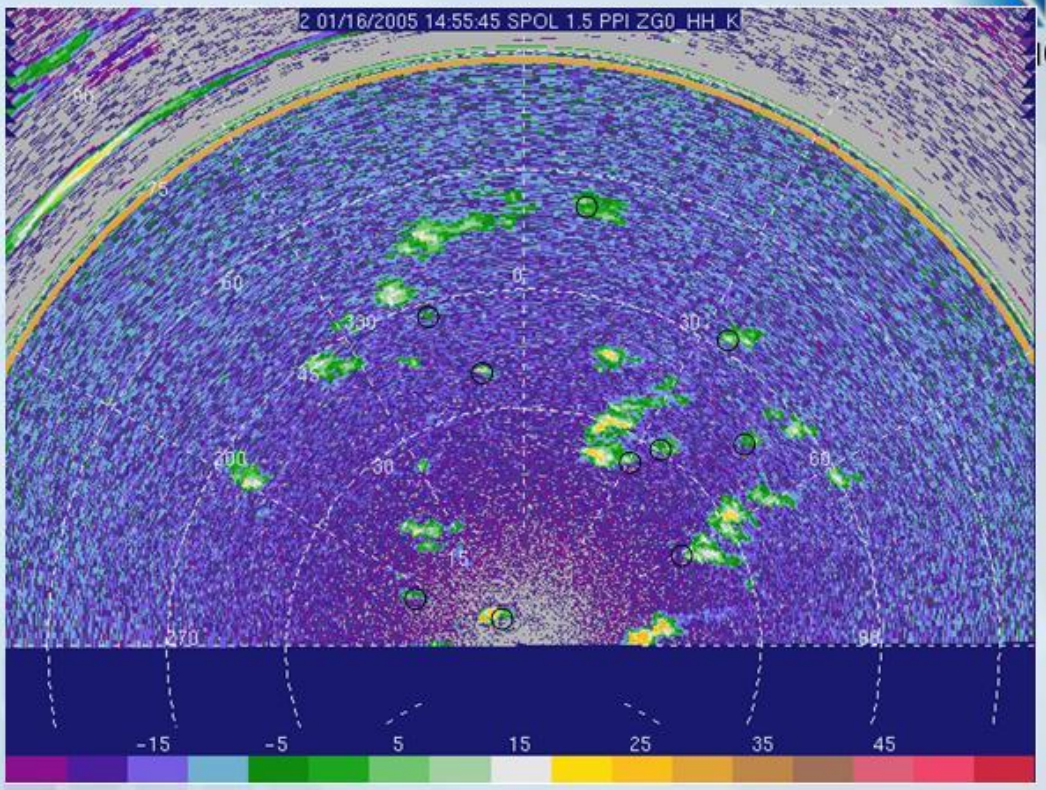
- Not simple
  - Careful selection of cases
  - Ka attenuation changes with range/height
  - May be problems with Ka Bragg scattering (?)
- Not necessarily stable over time
- Used only ZG0_HH_K with S DBZ
- Need to re-check with Z_HH_K
- Method is still evolving
- A detailed description available for those who need to know (off-line, later)

Z-Comparison Case Selection

NCAR




2 01/16/2005 14:55:45 SPOL 1.5 PPI ZG0_HH_K
-15
-5
5
15
25
35
45

Basics

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- Two unknowns: bias, attenuation
- Multiple pairs of echoes/equations
- Schematically:

$$\Delta Z_1 = (dBZ_S - dBZ_K)_1 = \text{Bias} + \text{Attn} * 2R_1$$

$$\Delta Z_2 = (dBZ_S - dBZ_K)_2 = \text{Bias} + \text{Attn} * 2R_2$$

$$\Delta Z_2 - \Delta Z_1 = 2 * \text{Attn} * (R_2 - R_1)$$

$$\text{Attn} = (\Delta Z_2 - \Delta Z_1)/2(R_2 - R_1)$$

Solve any/all: $\text{Bias} = \Delta Z - \text{Attn} * 2R$

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- **Results**:
  - Reflectivity bias between 1.5 and 4.5 dBZ
    (Corrected Ka is often higher than S-band DBZ)
  - One-way Ka gaseous attenuation ~.2 dB/km
  - Varying bias largely due to Ka tx power meas.

(That's all I'll say about this)

As for the Antenna Camera

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Well, the clock drifted.
We need a modified display tool.
Need to rename 5.5 M images.
Need to link time to az/el

NTP daemon failed!
Current one blows-up!
Names include exact time!
Prep work is done, but …

(maybe another time)

Wrapping-Up

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- We're making progress
- We're not done (another 1-2 months?)
- Data will be very usable, but will require awareness on part of scientist

  (possible exception: Ka Zdr?)
- Can use help: need to get test data to scientists, and request feedback.

NCAR

Special thanks to
all who have contributed
to this presentation, and to
those who continue to
work on the S-PolKa
data quality
and
data set.