CloudSat’s Cloud Profiling Radar (CPR): status, performance and new products

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**CPR Status**

- **CPR is currently operating at better than required performance**
  - Minor aging of hardware components to date (June 2009) has minor impact on radar performance and data quality. Still on primary side Tx.
  - End-to-end radar stability is estimated to be better than 0.6 dB in the first 3 years of operation, 0.7 dB to date. Prime Mission successfully completed in Feb 2008.
- CPR has been collecting data continuously with few exceptions:
  - CPR has stopped transmitting several times for brief periods (few minutes) to allow planned spacecraft maneuvers
  - CPR has stopped transmitting for a few days in 5 occasions (Sept. ’06, Mar. ’07, Apr. ’07, Jan ’08 and May ’08): all were triggered by the spacecraft autonomous fault response, in all instances the radar was brought back online and did not suffer damage.
  - CPR has stopped transmitting for 7 minutes on 5 occasions (June and July ’06, August ’07, Sept ’08 and May ’09): all were triggered by CPR/HPA autonomous fault response, in all instances the radar came back online automatically and did not suffer damage.
• Avg Orbital Transmit power as measured by calibrator has fluctuated ~ 0.7 dB (as of May 2009)
• During the first two years, apparent drop in $P_t$ corresponds to an apparent increase in surface back scatter (>0.95 correlation) - Best estimate is that actual transmit power, and receiver gain have been stable to better than 0.4 dB during Prime Mission. See IEEE TGRS Tanelli et al. 2008.

$$\sigma^0 = \frac{P_r}{P_t} Cr^2 \Delta$$

$$\frac{\sigma^0_{ref}}{\sigma^0} = \frac{P_t}{P_{t,ref}}$$
CPR Calibration/Validation

High quality external calibration and validation assessment made possible by

- A-TRAIN (CALIPSO & AMSR-E)
- Philippa A.M. Berry and Susan M.S. Bramer, DeMontfort U. Leicester U.K. - Independent Assessment
- Alain Protat, Gerald Heymsfield, Mengistu Wolde, Dave Leon, Richard Austin, and many others - (Validations from multiple instruments, mainly W-band radars)
- Joel Johnson and Nino Majurec, Ohio State U. – Advanced scattering models – Multi frequency comparison.
- Hiroaki Horie et al. NICT/JAXA team – Experimental active calibration experiment, best pulse shape observation to date.
- Jacques Pelon, Damien Josset and Hu Yongxiang – CPR/CALIOP cross-calibration
- ECMWF, ARM, NCEP
Surface Backscattering modeling advancement

- Cloud Sat data are being used to analyze and improve modeling of surface backscatter. Should coordinate with CALIPSO team. Two posters in this workshop:
  - Durden et al.
  - Majurec et al.
Transmitter Switchover Plan

- Entry condition: minimum detectable sensitivity projected 6 months into the future at the current trend violates EOL requirement of -26 dBZ.
  - Mission Operations Team will issue warning to PI, ADWG and STM
  - PI, ADWG and STM will provide input on upcoming periods of high interest (i.e., to avoid execution of switchover in the middle of a field experiment).
- Execution: within the 6 months window.
- Expected “blind” period: in absence of anomalies 2-4 days.
- Calibration period (i.e., delay in release of L1B data from redundant side): 1-2 months, initially limited to Science Team.
CPR as Radiometer

- CPR noise power converted into brightness temperature using relationship obtained by comparing with AMSR-E 89-GHz TB
- Preliminary estimation of $\Delta T \cong 5K$

Ocean, clear sky (Jan 1-17, 2007)  
Land, clear sky (Jan 1-17, 2007)

Ocean, cloudy sky (Jan 1-17, 2007)  
Land, cloudy sky (Jan 1-17, 2007)

- Cold background (ocean) appears warmer in the presence of water cloud
CPR as Radiometer
Tb product: step 1

- Calculate CPR noise from L1B-CPR ReceivedEchoPowers
  - Use L2B Cloud Mask and sem_noise_floor to flag ‘cloudy bins’ in the ‘noise region’.
    - Iter #1: 4-sigma above mean
    - Iter #2: 3-sigma away from mean
  - Option (Flag all bins beyond #85 in GEOPROF (i.e., lowest 5 km))
  - Option (Flag all bins with Lidar echo)
  - Use all unflagged bins to calculate mean noise of each ray
- Filter CPR 1-ray noise along track
  - Apply moving average filter with 6 window sizes, (1, 5, 11, 31, 61, 101)
  - Adopt largest window in which noise population is distributed according to expectation.
- Convert noise to Brightness Temperature:
  - TB94 = filtered_noise * C1 + C2
  - C1 = 189 \times 10^{15}
  - C2 = -670
  - Coefficients calculated from AMSR-E 89H Tb, Ws, SST, and WVmm using lookup table
    - Tb 89H 55° --> Tb 94 0.16° with 1-D Radiative Transfer over ocean and clear air (Eddington Approximation)
Step 1: zoom in
Tb product: step 2

- Calculate CPR noise from L1B-CPR ReceivedEchoPowers
  - Use L2B Cloud Mask and sem_noise_floor to flag ‘cloudy bins’ in the ‘noise region’.
    - Iter #1: 4-sigma above mean
    - Iter #2: 3-sigma away from mean
  - Option (Flag all bins beyond #85 in GEOPROF (i.e., lowest 5 km))
  - Option (Flag all bins with Lidar echo)
  - Use all unflagged bins to calculate mean noise of each ray

- Filter CPR 1-ray noise along track
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    - Tb 89H 55° \rightarrow Tb 94 0.16° with 1-D Radiative Transfer over ocean and clear air (Eddington Approximation)
Tb product: step 3

- Calculate CPR noise from L1B-CPR ReceivedEchoPowers
  - Use L2B Cloud Mask and sem_noise_floor to flag
    ‘cloudy bins’ in the ‘noise region’.
    - Iter #1: 4-sigma above mean
    - Iter #2: 3-sigma away from mean
  - Option (Flag all bins beyond #85 in GEOPROF (i.e.,
    lowest 5 km))
  - Option (Flag all bins with Lidar echo)
  - Use all unflagged bins to calculate mean noise of each
    ray
- Filter CPR 1-ray noise along track
  - Apply moving average filter with 6 window sizes, (1, 5,
    11, 31, 61, 101)
  - Adopt largest window in which noise population is
    distributed according to expectation.
- Convert noise to Brightness Temperature:
  - \( TB94 = \text{filtered\_noise} \times C1 + C2 \)
  - \( C1 = 189 \times 10^{15} \)
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  - Coefficients calculated from AMSR-E 89H Tb, Ws,
    SST, and WVmm using lookup table
    - Tb 89H 55° --> Tb 94 0.16° with 1-D Radiative Transfer
      over ocean and clear air (Eddington Approximation)
Parameters used to find constants via lookup table

From AMSR-E

- TB89H
- Water vapor
- Wind Speed
- Sea Surface Temperature

![AMSRR Water Vapor 2007033-2008035](image)

![AMSRR Wind Speed 2007033-2008035](image)

![AMSRR Sea Surface Temperature 2007033-2008035](image)
Tb product: step 3
Tb Product Status

- Code has been test run over several periods by the DPC
- Will be distributed for more testing
- Data will be added to 2B-GEOPROF output and stored in separate product file (name TBD) with R05
  - Single ray noise avg
  - Single ray number of noise bins
  - Single ray noise std dev
  - Filter window size
Temporal drift due to Receiver Gain drift

Jan 2008 $\langle T_b \rangle = 242.741$

Jan 2009 $\langle T_b \rangle = 239.401$
Jan & Jul TKW -CLR ocean avg =5.6477
Jan & Jul TNW - CLR
17 July 2008

black marker at ray 30, white at ray 60
Summary

- CPR is not a youngster anymore but still running strong
- Tb will be added to R05. This is an experimental product, feedback from STM is NECESSARY.