Ocean Precipitation Retrieval and Validation

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1st-Year Activities

- Analysis of aircraft-based radar and radiometer observations in Wakasa Bay (Ben Johnson)
  - Improved assumptions concerning hydrometeor microphysical and microwave properties in snow and shallow rain clouds.
- New Coupled-Dipole (aka DDA) code optimized for computing microwave scattering and extinction properties of complex snow aggregates (Wei Huang)
  - Validation of standard models (e.g., equivalent sphere, dielectric mixing formulas)

1st-Year Activities (cont.)

- End-to-end AMSR swath simulator (all)
  - Cloud model -> Hydrometeor assumptions -> Microwave models -> 3D RT model -> sampling/average to sensor geometry
  - Validation of simulated retrievals
  - Evaluation of error sources
- Passive microwave community resources web site development (Petty)
- **Alternative ocean precip algorithm validation and improvement** (Longtao Wu)

Algorithm Milestones

- Algorithm developed for SSM/I (Petty 1995, Met. Atmos. Physics)
- Adapted to AMSR, AMSR-E with support from NASDA (now JAXA)
- Beginning Summer 2004: First *direct* NASA support for validation/calibration of this algorithm.
- Integration into Direct-Broadcast algorithm package distributed by UW-Madison/CIMSS (in progress)

Algorithm Philosophy

- Vertical structure not considered (except for effective rain layer depth), focus instead on **horizontal structure**.
- Emphasis on
  - utilization of polarization to decouple scattering and attenuation (now also used in GPROF)
  - utilization of multichannel info to resolve *horizontal* structure at highest possible resolution (mitigates FOV-filling biases)
  - robust detection of light, shallow, and/or high latitude ocean precipitation
- 89 GHz scattering info used *only* for first-guess *or* when other channel info not useful.

Algorithm Validation Milestones

- Participation in AIP-3 and PIP-3 (SSM/I version)
  - In AIP-3: Highest overall linear correlation with 0.25 degree radar rain rates (out of approx. 27 SSM/I algos.)
    - Validates approach to high resolution horizontal structure
    - Vindicates neglect of vertical structure?
  - In PIP-3: Only algorithm to yield *all* of the following
    - Reasonable mid- and high-latitude precipitation *fractional-time-precipitating* as compared with ship-based climatology
    - Reasonable correlation *and* bias relative to tropical atolls
    - Reasonable reproduction of annual cycle
- *No empirical calibration of rain amounts or inversion scheme prior to above activities!*

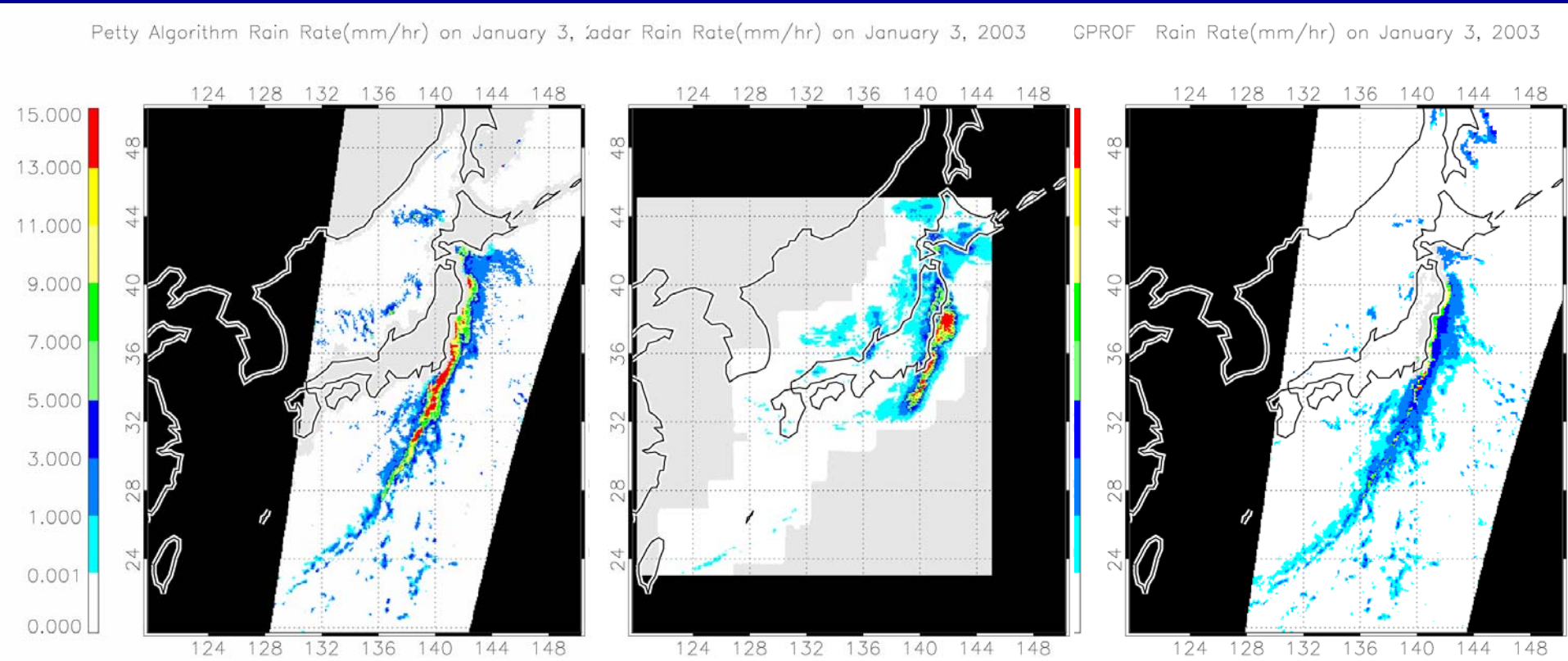
Algorithm Validation Milestones (cont.)

- Participation in JAXA internal intercomparisons (initial AMSR version; no calibration)
  - Pronounced low bias in tropical areas
    - Apparent role of 10.65 GHz channels (no large bias in SSM/I version!)
  - Apparent high bias in high latitudes
    - Too many pixels classified as precipitating
    - Scattering-based precip rate estimate too high in those pixels.
    - AMSR calibration?

Algorithm Validation Milestones (cont.)

- *First* significant in-house calibration effort in progress as of Fall 2004 (student Longtao Wu)
  - Radar-AMSR matchups from JAXA (esp. winter)
  - Precipitation frequency from ship climatology
  - Tropical atoll monthly rainfall
- Fixes:
  - increased liquid water thresholds for precip "maybe/no" screen
  - empirical first-guess S_{89}-R relationship
  - reduced "effective" rain layer depth (75% of freezing level).

Comparisons with Japanese AMeDAS Radar Network (matchups courtesy of JAXA)

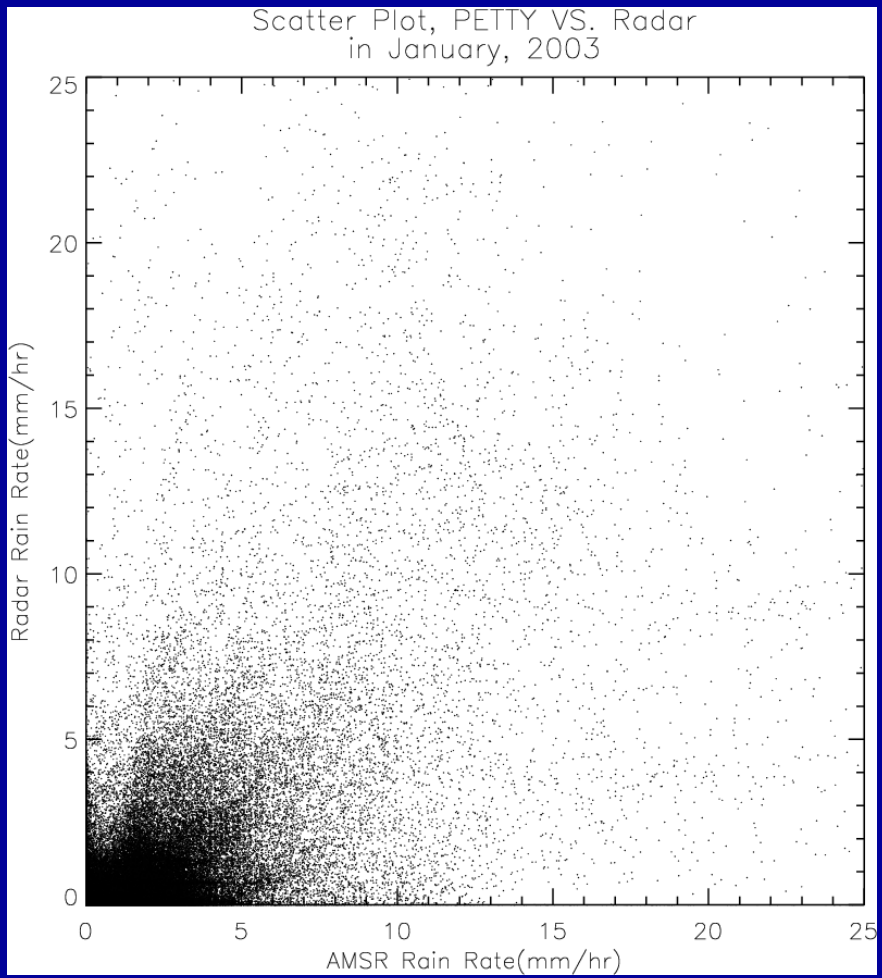


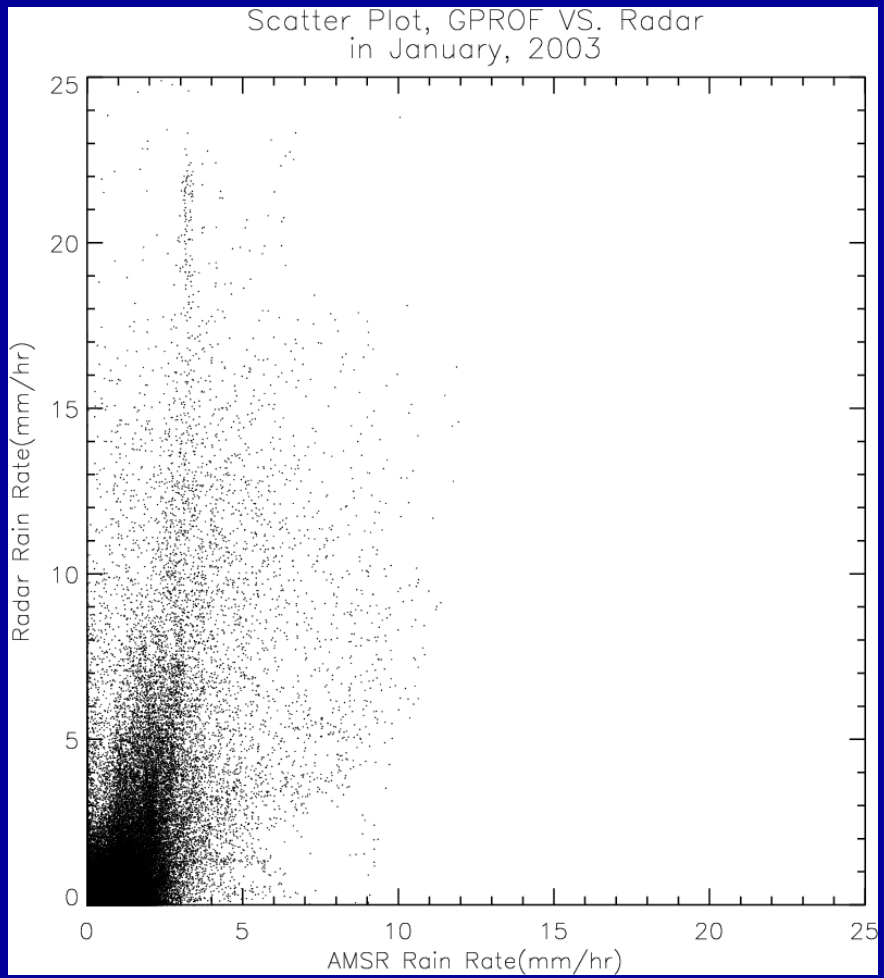
Methodology – Radar Comparisons

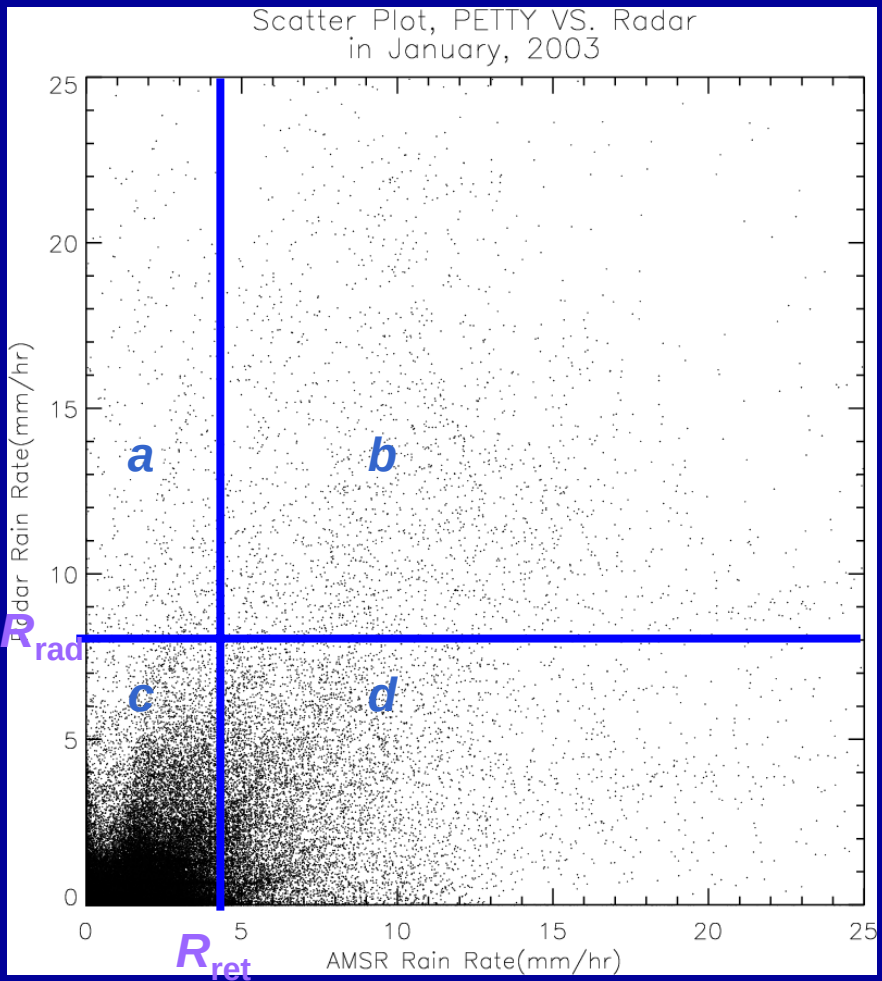
- Include only grid boxes where precip total over entire matchup sample exceeds some minimum.
- Compute Heidke Skill Score (HSS) as function of variable rain rate thresholds (separate for retrieval and validation)
  - Using algorithm threshold R_{ret}, compute skill of algorithm at delineating radar rain rates greater than R_{rad}.
  - When R_{ret}=0 and R_{rad}=0 , result is equivalent to conventional HSS applied to rain/no-rain determination.

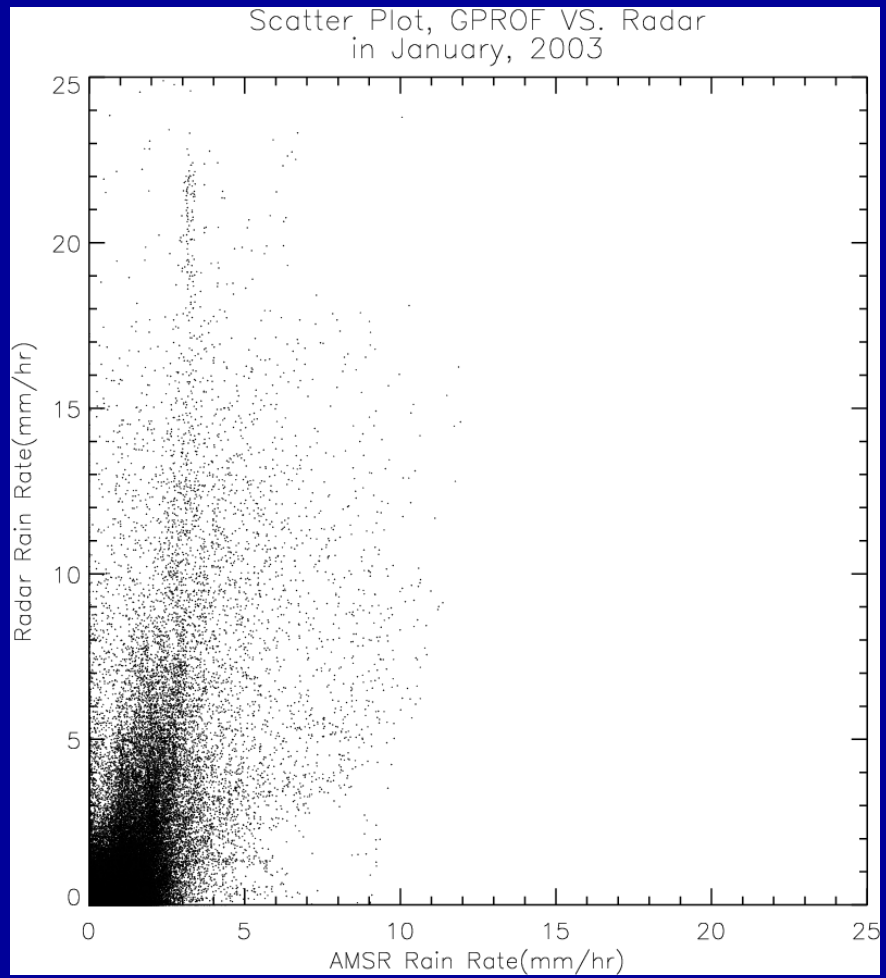
Two-threshold HSS (cont.)

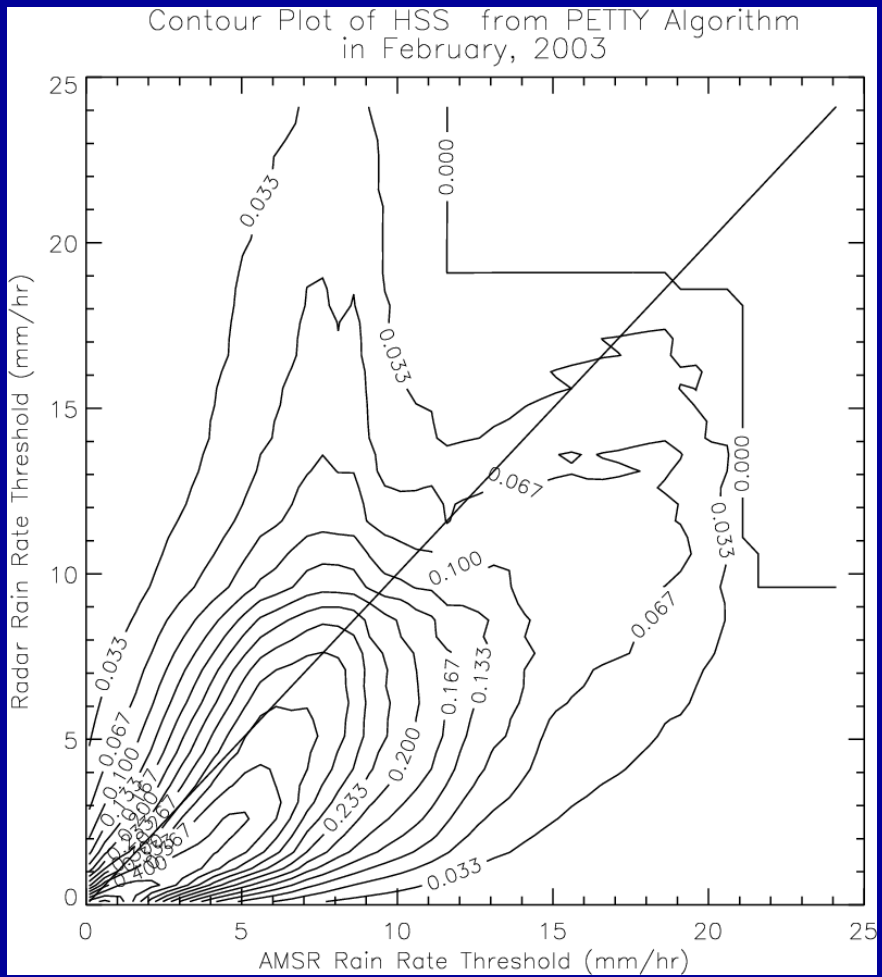
- Determine *maximum* skill as function of R_{rad}
- Invariant with respect to (non-linear!) calibration biases in either the retrievals or the validation data.
- Can assess relative “intrinsic” performance of different algorithms at low, intermediate, and high rain rates *without respect to biases*.

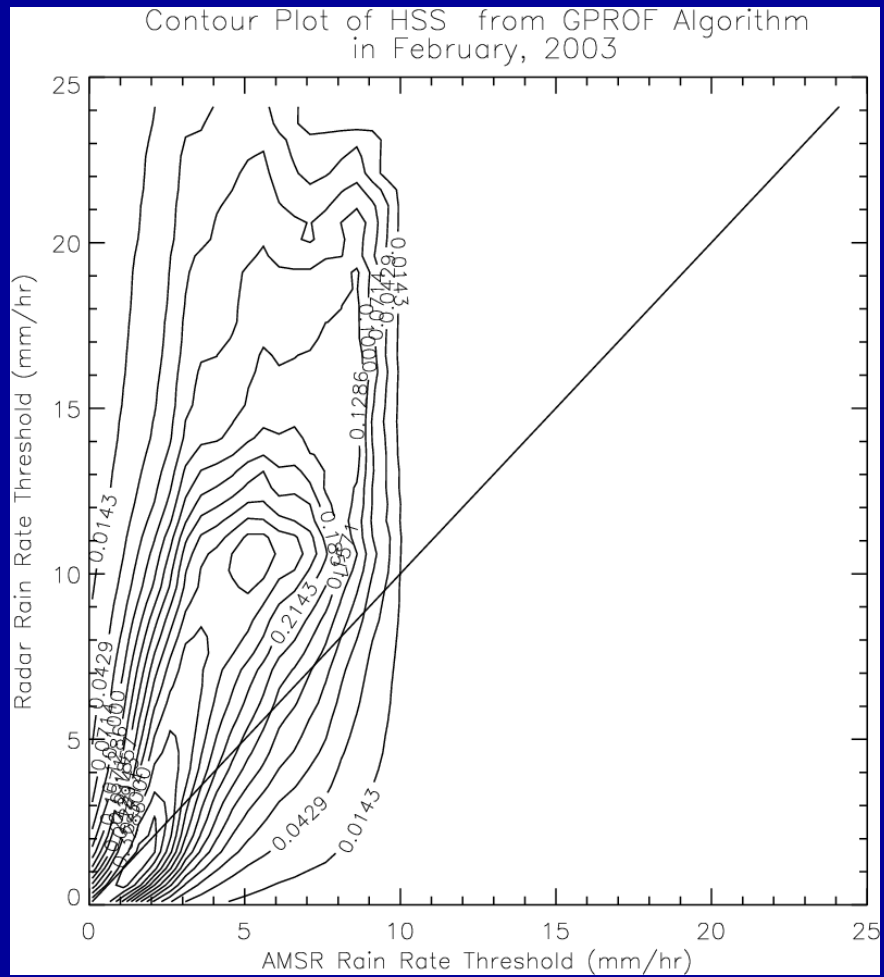

Scatter Plot, PETTY VS. Radar
in January, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25

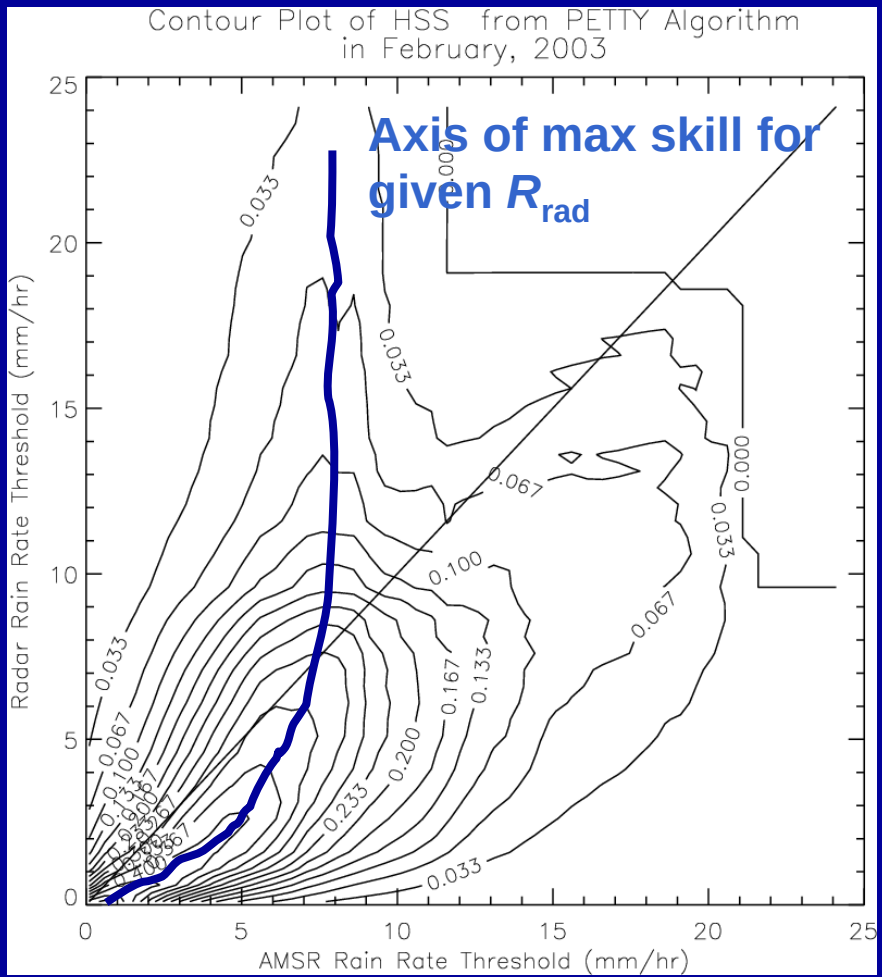

Scatter Plot, GPROF VS. Radar
in January, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25

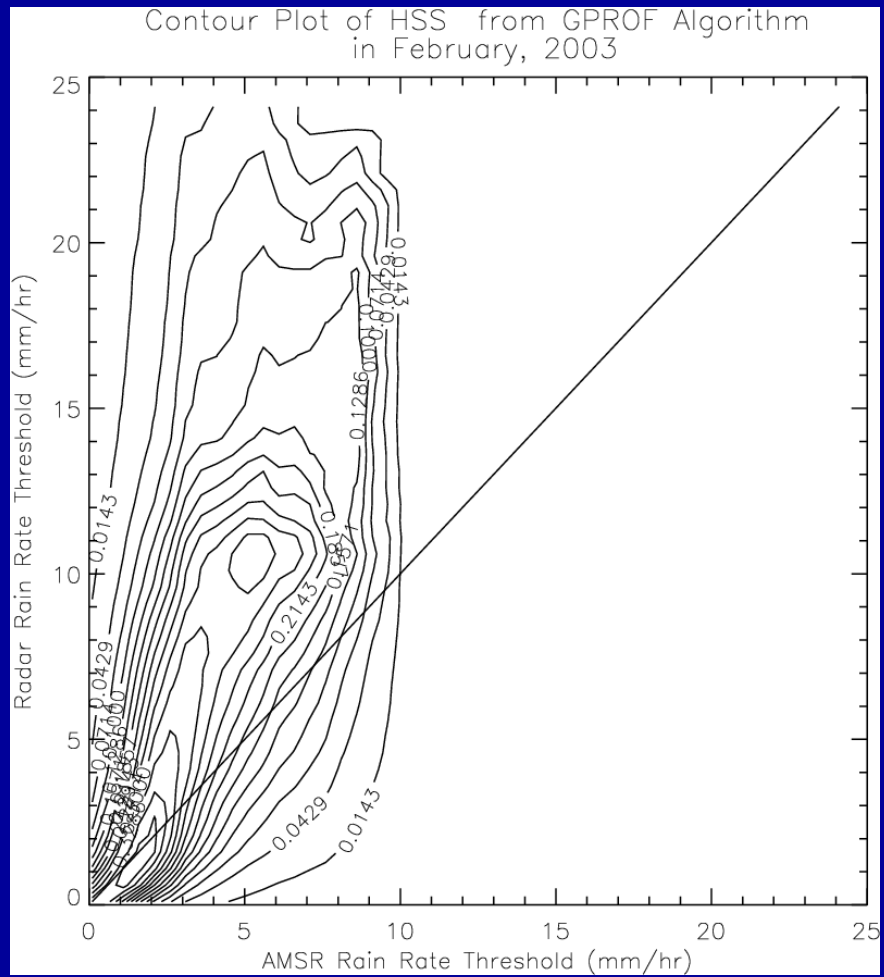

Scatter Plot, PETTY VS. Radar
in January, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
a
b
c
d
R_{rad}
R_{ret}
0
5
10
15
20
25


Scatter Plot, GPROF VS. Radar
in January, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25


Contour Plot of HSS from PETTY Algorithm
in February, 2003
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.000
0.033
0.067
0.100
0.133
0.167
0.200
0.233

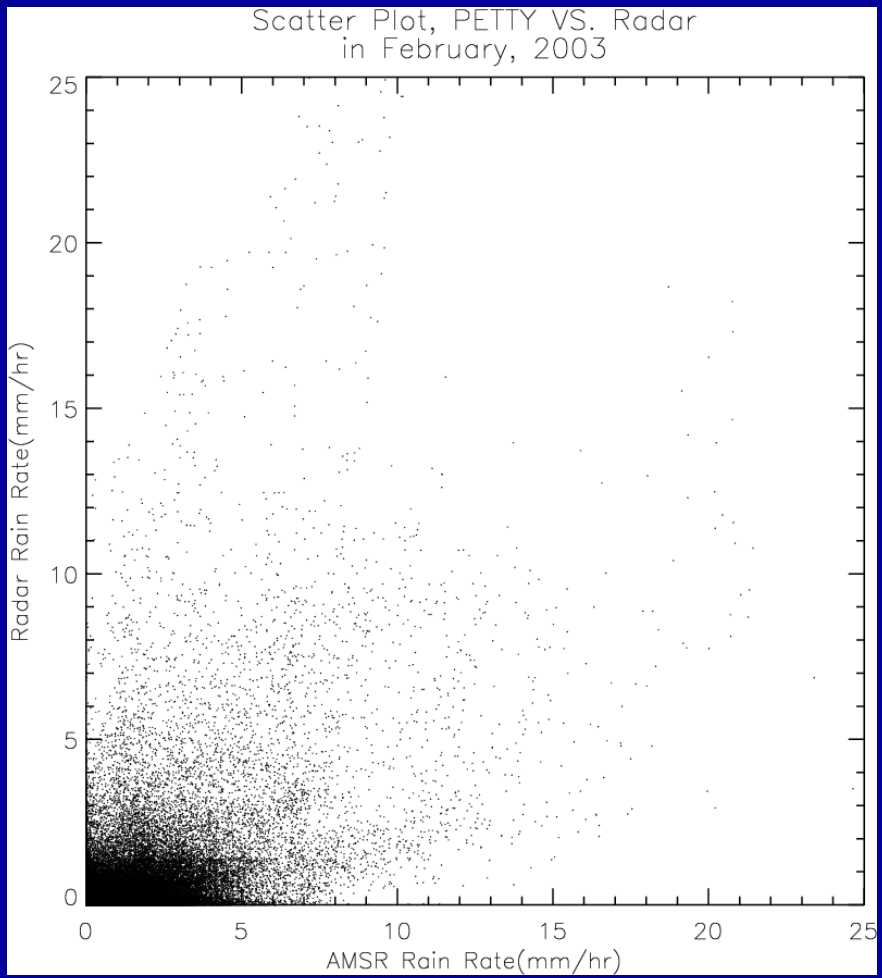

Contour Plot of HSS from GPROF Algorithm
in February, 2003
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.0143
0.0429
0.0716
0.1000
0.1286
0.1571
0.2143

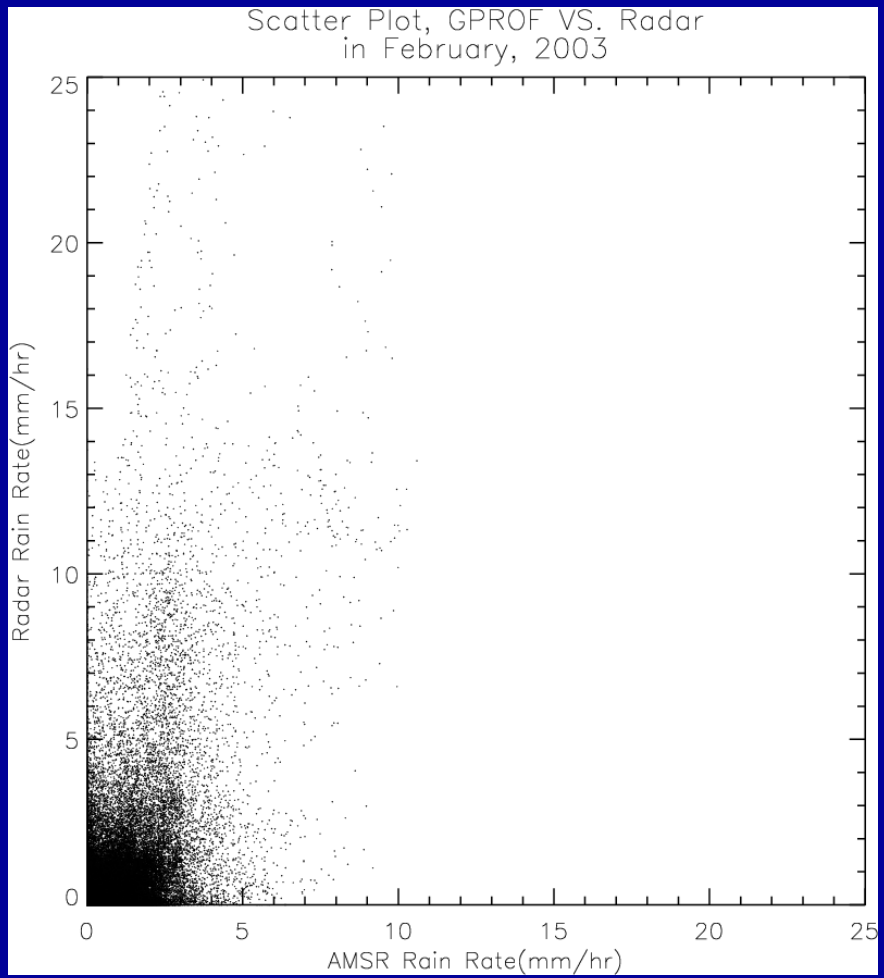

Contour Plot of HSS from PETTY Algorithm
in February, 2003
Axis of max skill for given R_{rad}
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.033
0.067
0.100
0.133
0.167
0.200
0.233
0.000

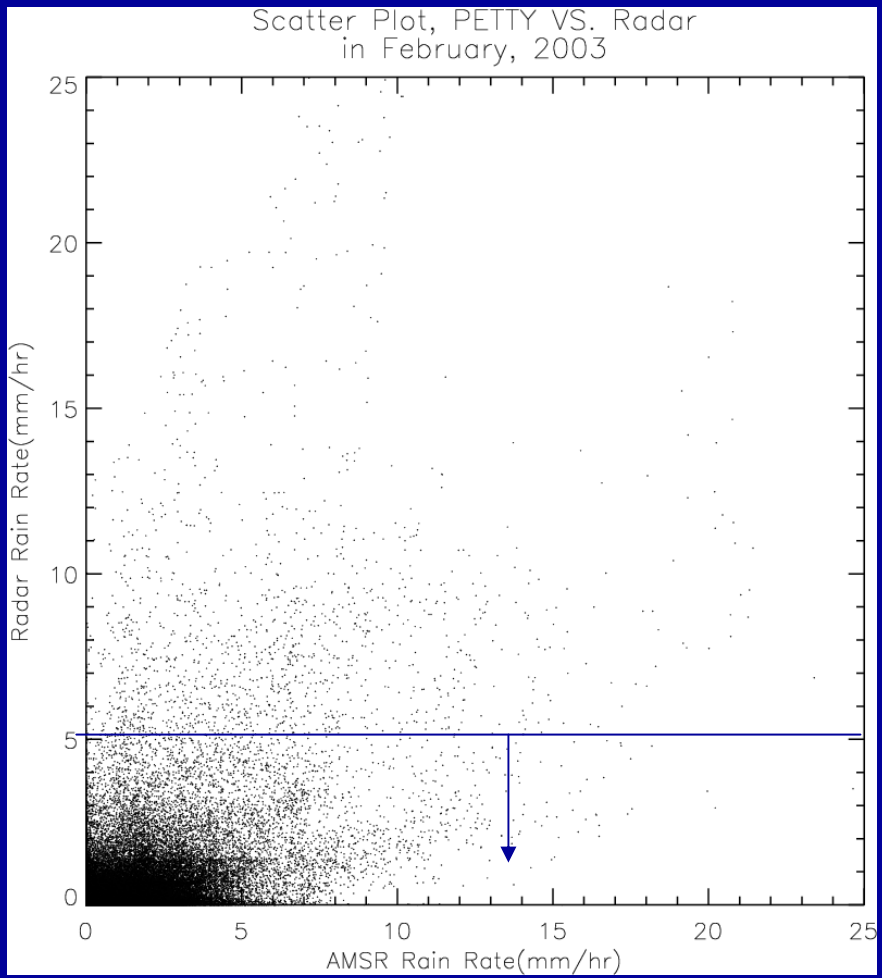

Contour Plot of HSS from GPROF Algorithm
in February, 2003
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.0143
0.0429
0.0716
0.1000
0.1286
0.1571
0.2143

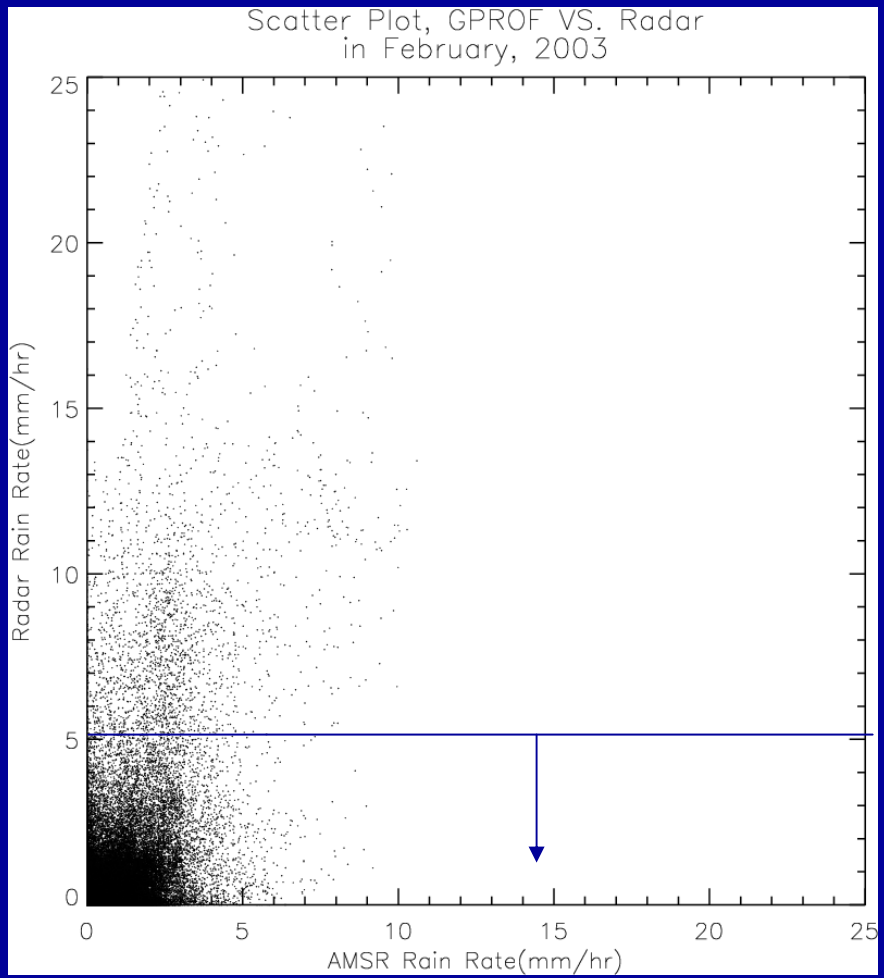
HSS (cont.)

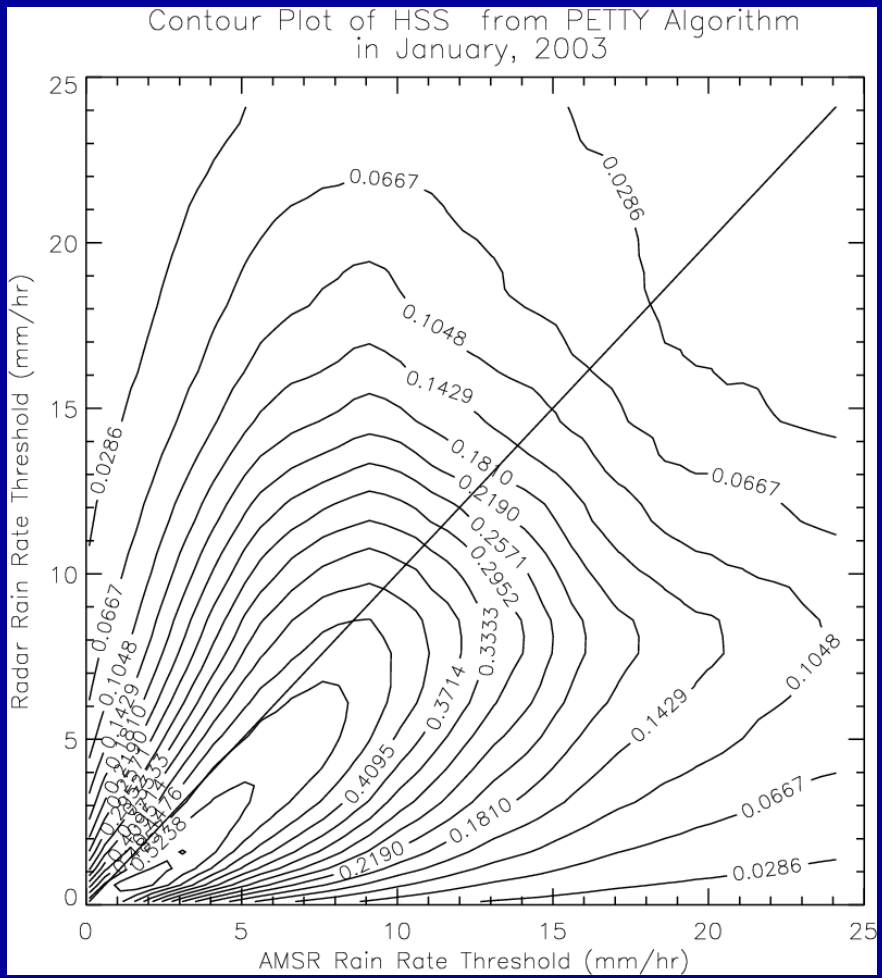
- For a given validation rain rate threshold R_{rad}, what is the *maximum* skill that a particular algorithm achieves in delineating rain rates higher than R_{rad}? --*"Intrinsic" skill!*
- What is the value of R_{ret} that achieves the above maximum skill? – *Calibration!*

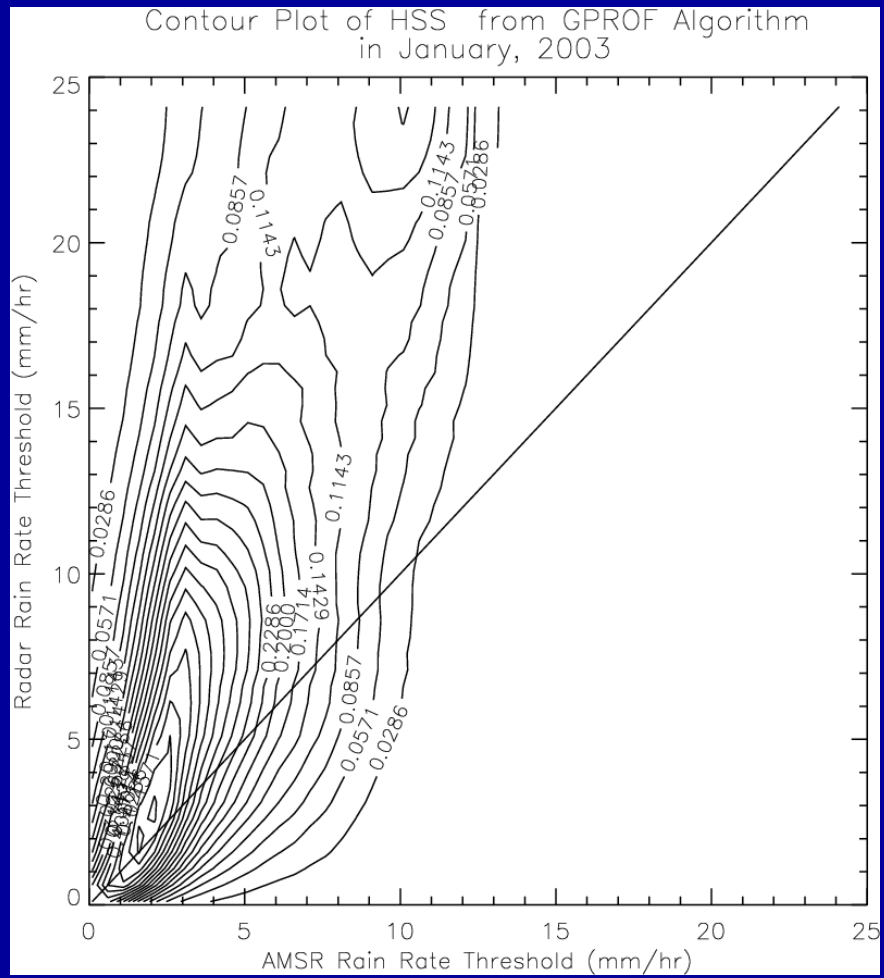

Scatter Plot, PETTY VS. Radar
in February, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25

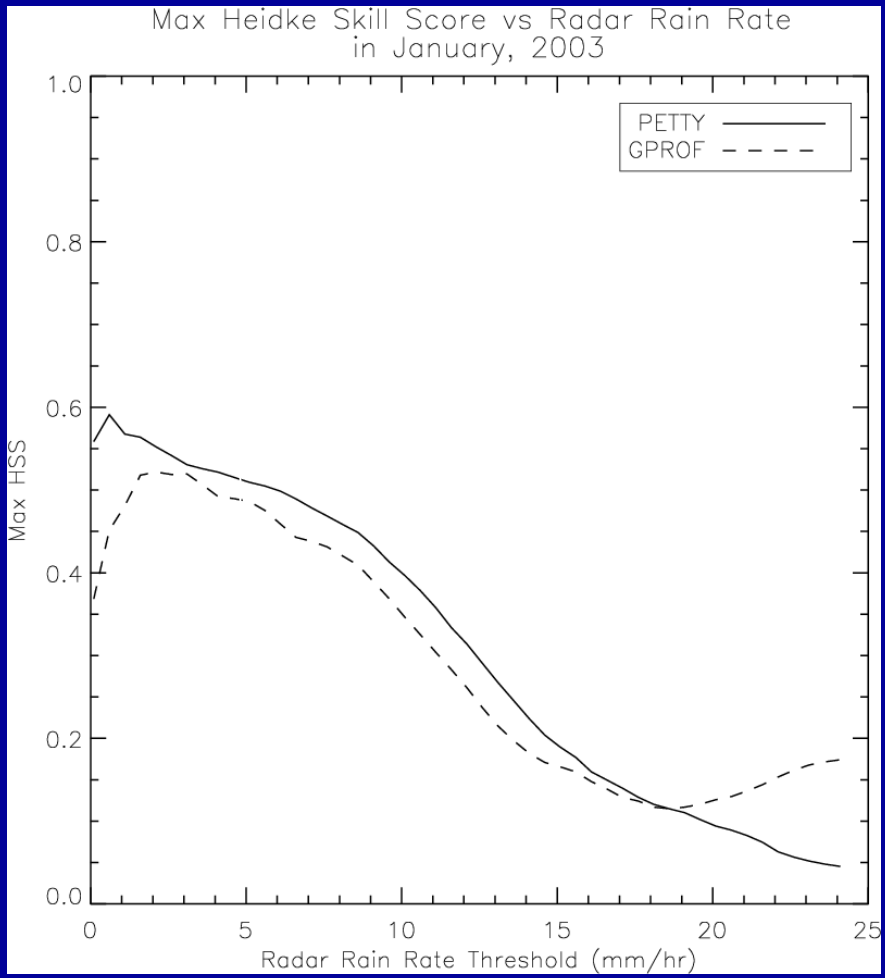

Scatter Plot, GPROF VS. Radar
in February, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25

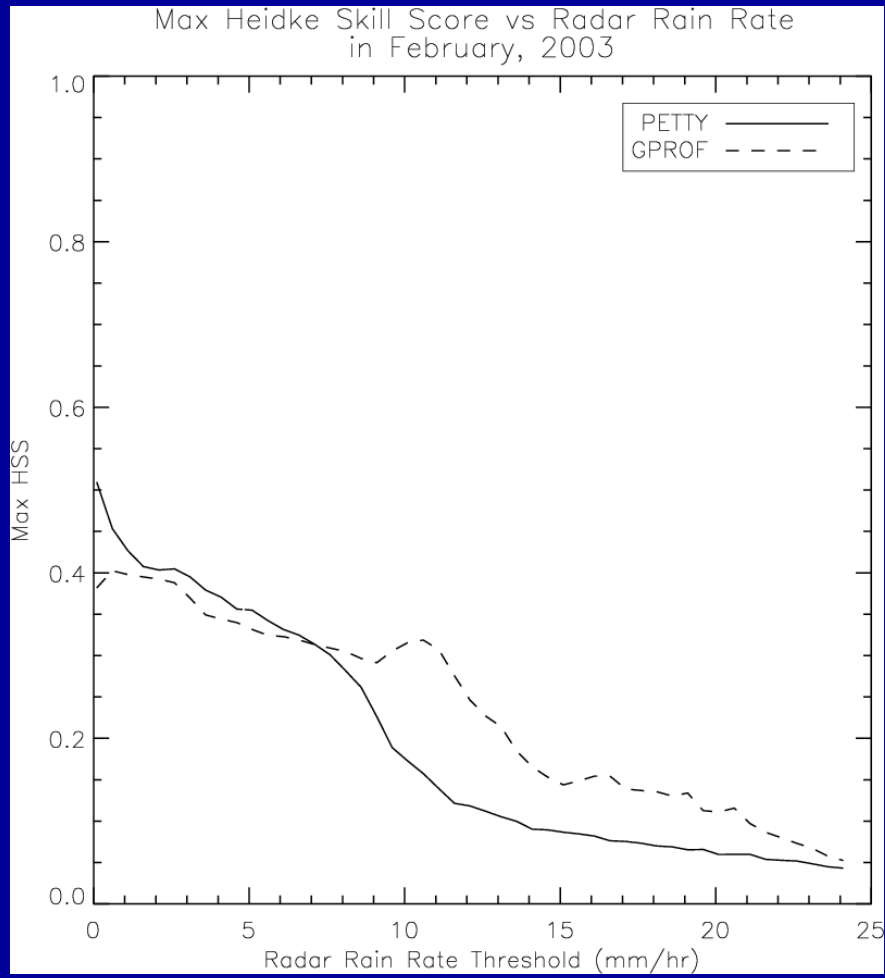

Scatter Plot, PETTY VS. Radar
in February, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25


Scatter Plot, GPROF VS. Radar
in February, 2003
Radar Rain Rate(mm/hr)
AMSR Rain Rate(mm/hr)
0
5
10
15
20
25


Contour Plot of HSS from PETTY Algorithm
in January, 2003
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.0667
0.0286
0.1048
0.1429
0.1810
0.2190
0.2571
0.2952
0.3333
0.3714
0.4095


Contour Plot of HSS from GPROF Algorithm
in January, 2003
Radar Rain Rate Threshold (mm/hr)
AMSR Rain Rate Threshold (mm/hr)
0
5
10
15
20
25
0.0857
0.1143
0.0571
0.0286
0.1429
0.2286
0.2600
0.1714


Max Heidke Skill Score vs Radar Rain Rate
in January, 2003
PETTY
GPROF
Max HSS
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
Radar Rain Rate Threshold (mm/hr)


Max Heidke Skill Score vs Radar Rain Rate
in February, 2003
PETTY
GPROF
Max HSS
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
Radar Rain Rate Threshold (mm/hr)

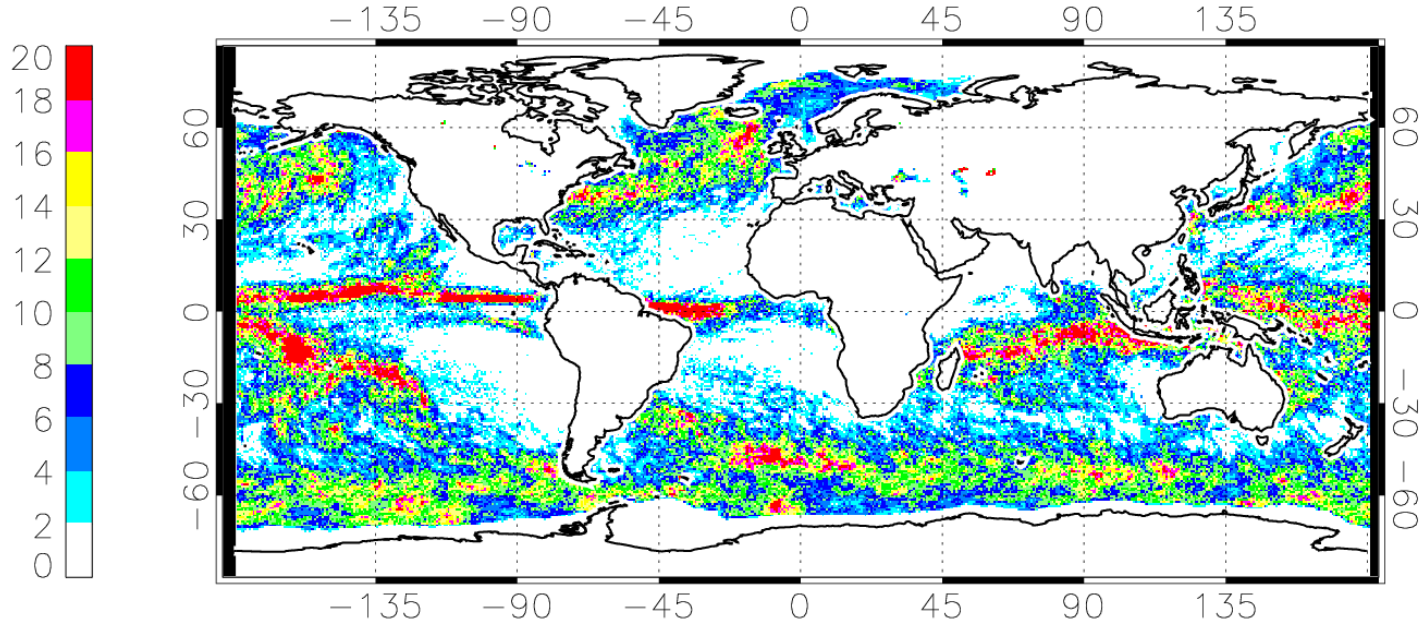
Summary – Preliminary Comparisons with Japan Radar (J/F 2003)

- Relative to standard algorithm (GPROF), UW-Madison algorithm seems to exhibit improved skill at *detecting/delineating* the lightest precip rates (< 5 mm/hr) in winter season.
- Possible (correctible) high bias at low rates, low bias at high rates.

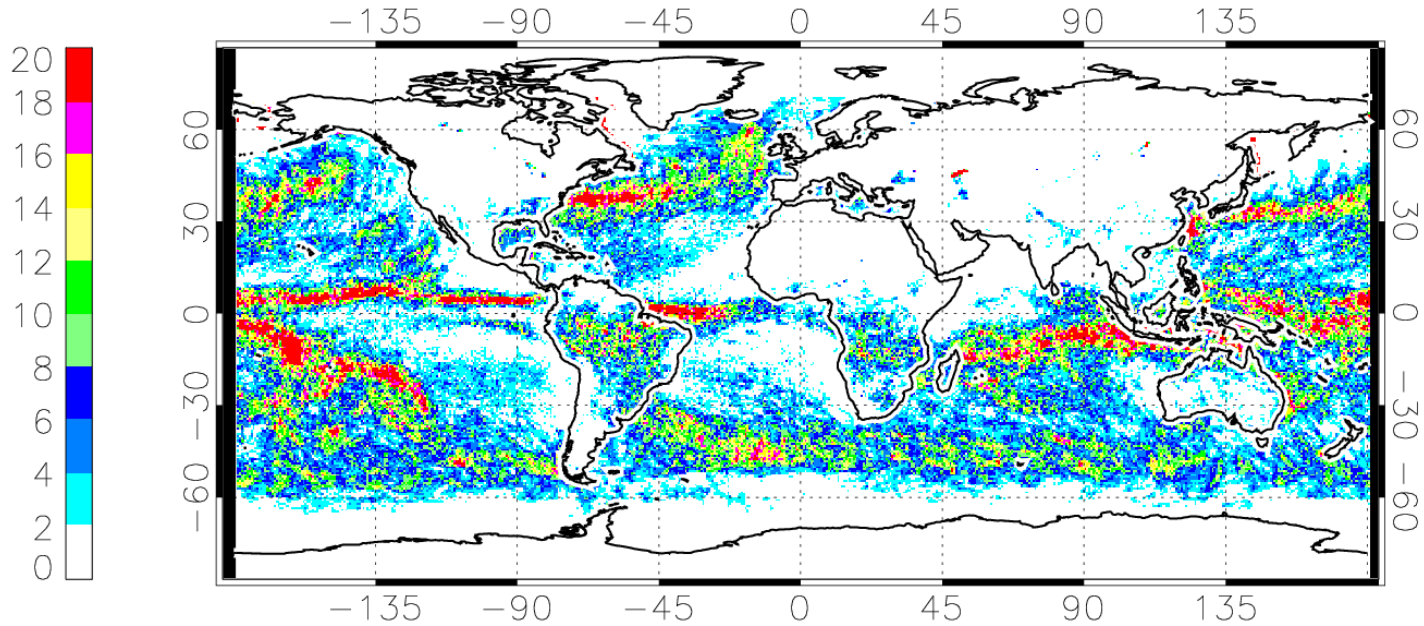
Validation of *Fractional Time Precipitating* (FTP)

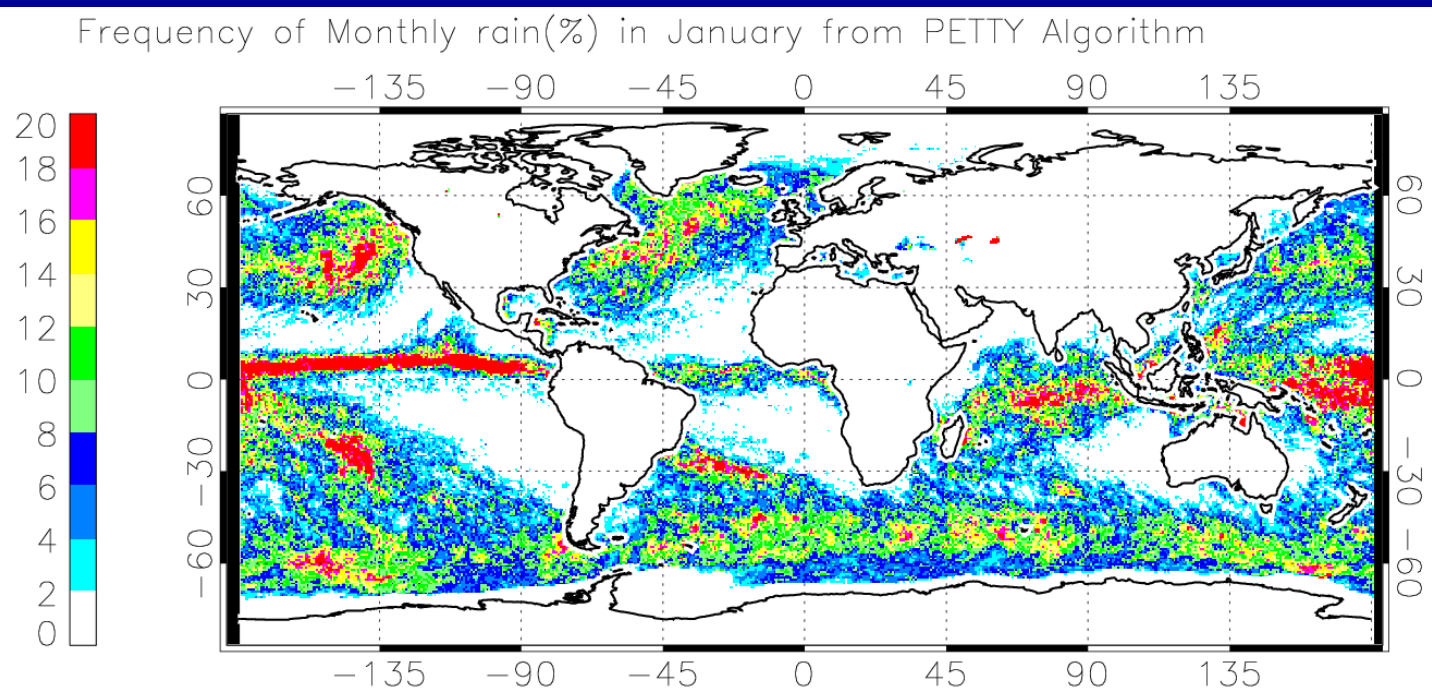
- For given month and lat/lon grid box, tabulate fraction of pixels (at native resolution) with R>0 (similar to PIP-3).
- Assess “reasonableness” of results in light of surface ship-based climatology of FTP (Petty, 1995).
- Special focus on high latitudes in light of large disparities between algorithms.

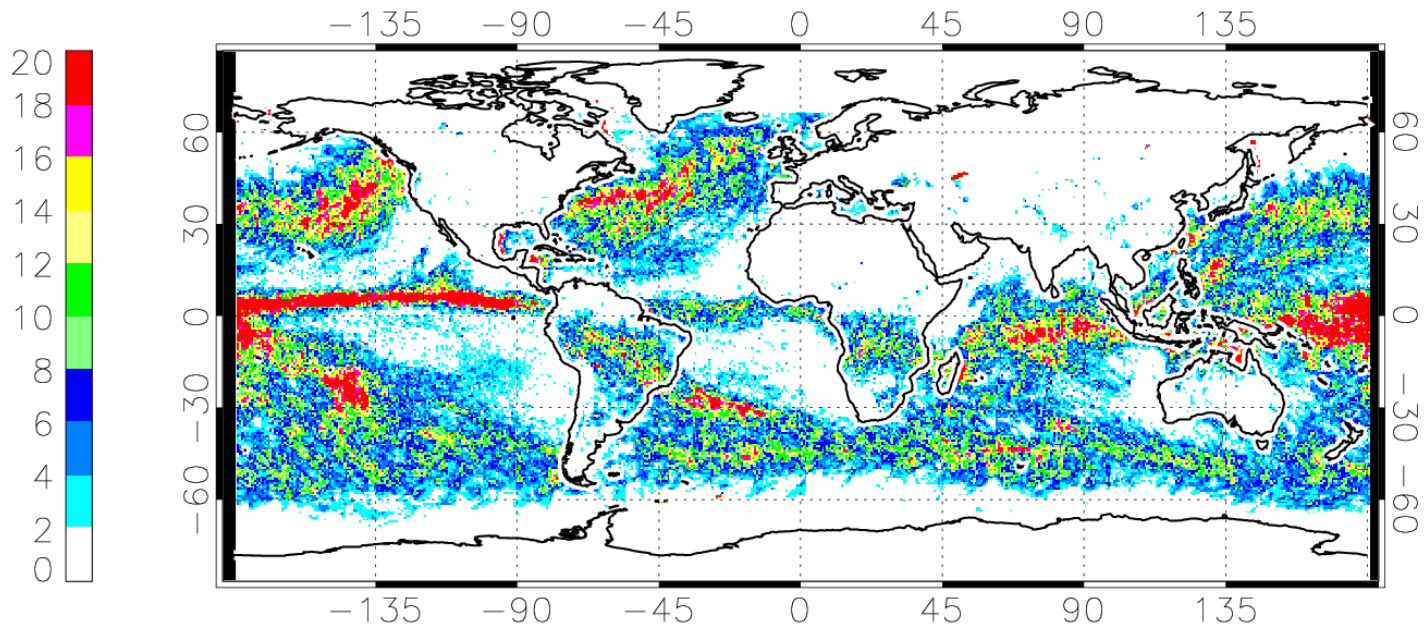
Frequency of Monthly rain(%) in February from PETTY Algorithm



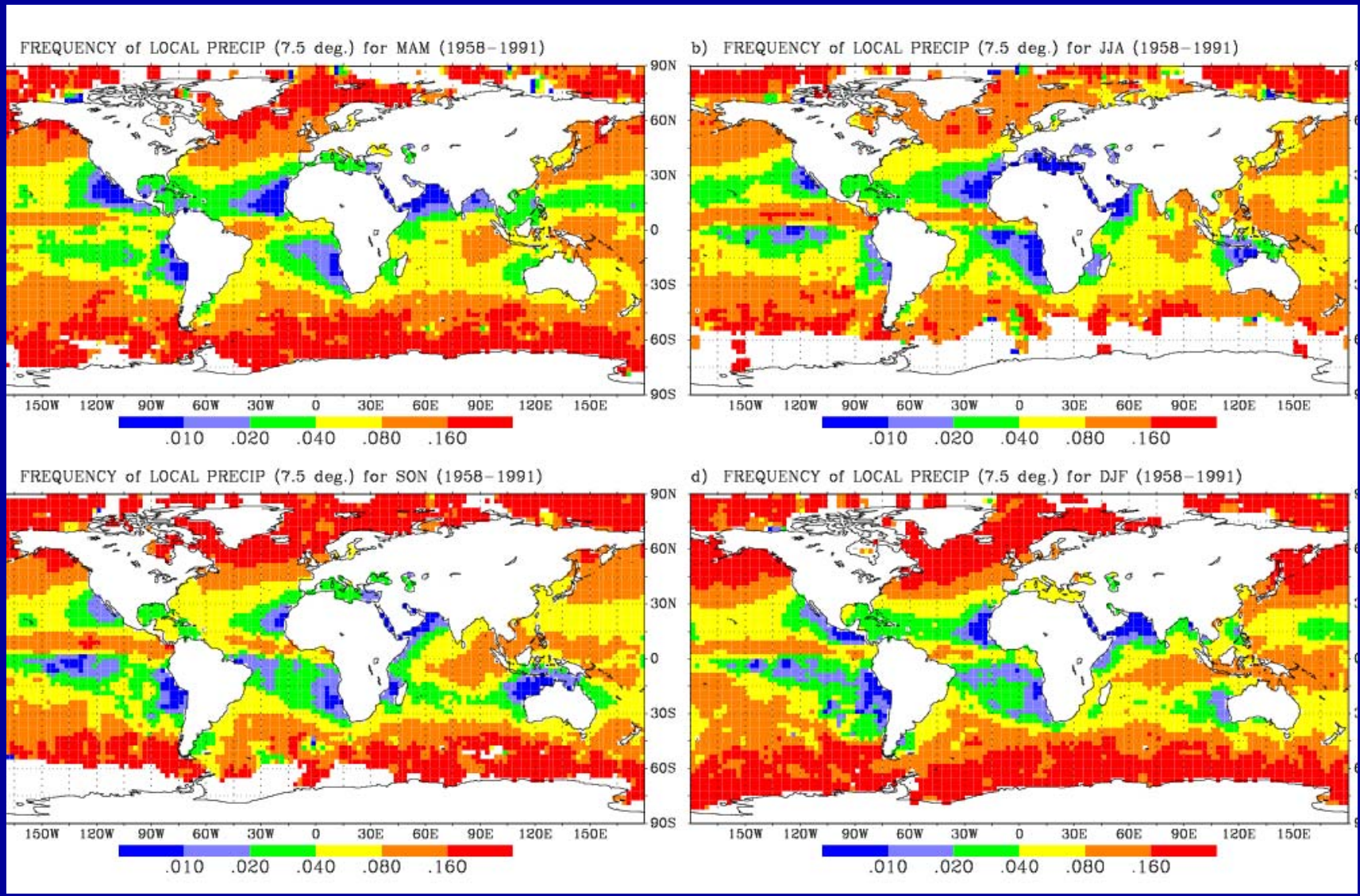
Frequency of Monthly rain(%) in Februaryfrom GPROF Algorithm




Frequency of Monthly rain(%) in January from PETTY Algorithm
20
18
16
14
12
10
8
6
4
2
0
−135
−90
−45
0
45
90
135
60
30
0
−30
−60


Frequency of Monthly rain(%) in Januaryfrom GPROF Algorithm
20
18
16
14
12
10
8
6
4
2
0
−135
−90
−45
0
45
90
135
60
30
0
−30
−60

Ship-based climatology (Petty 1995)

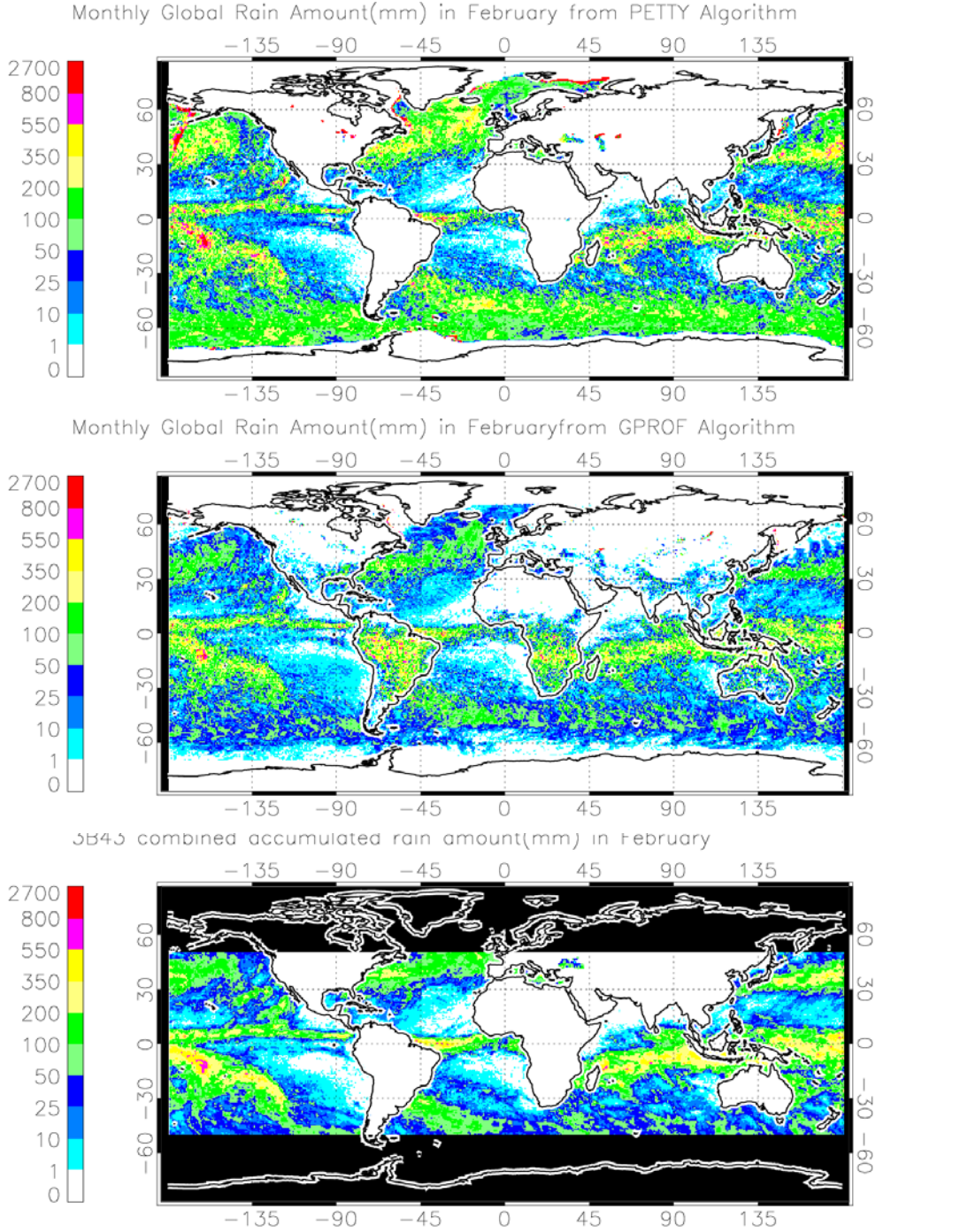


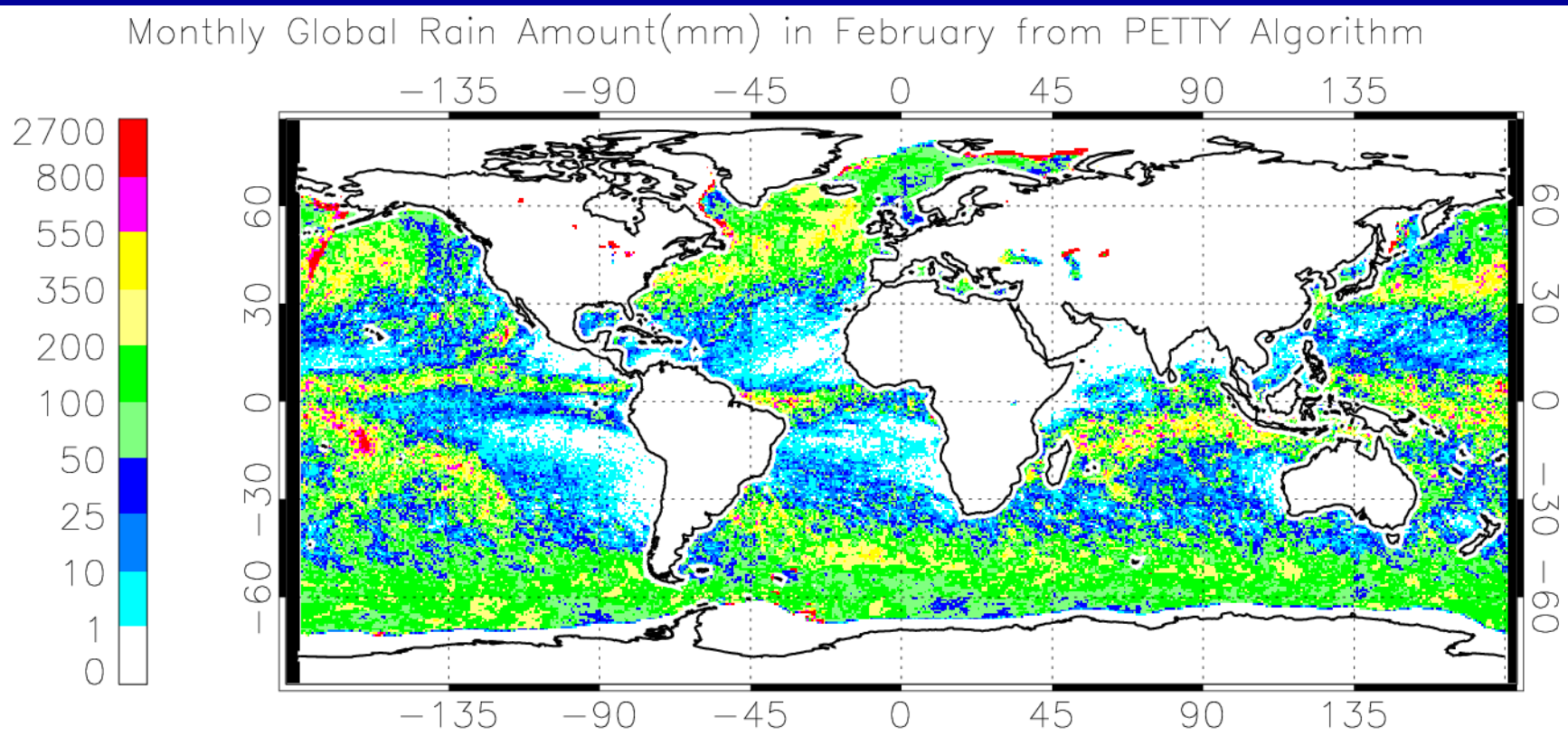
Summary – Preliminary evaluation of FTP

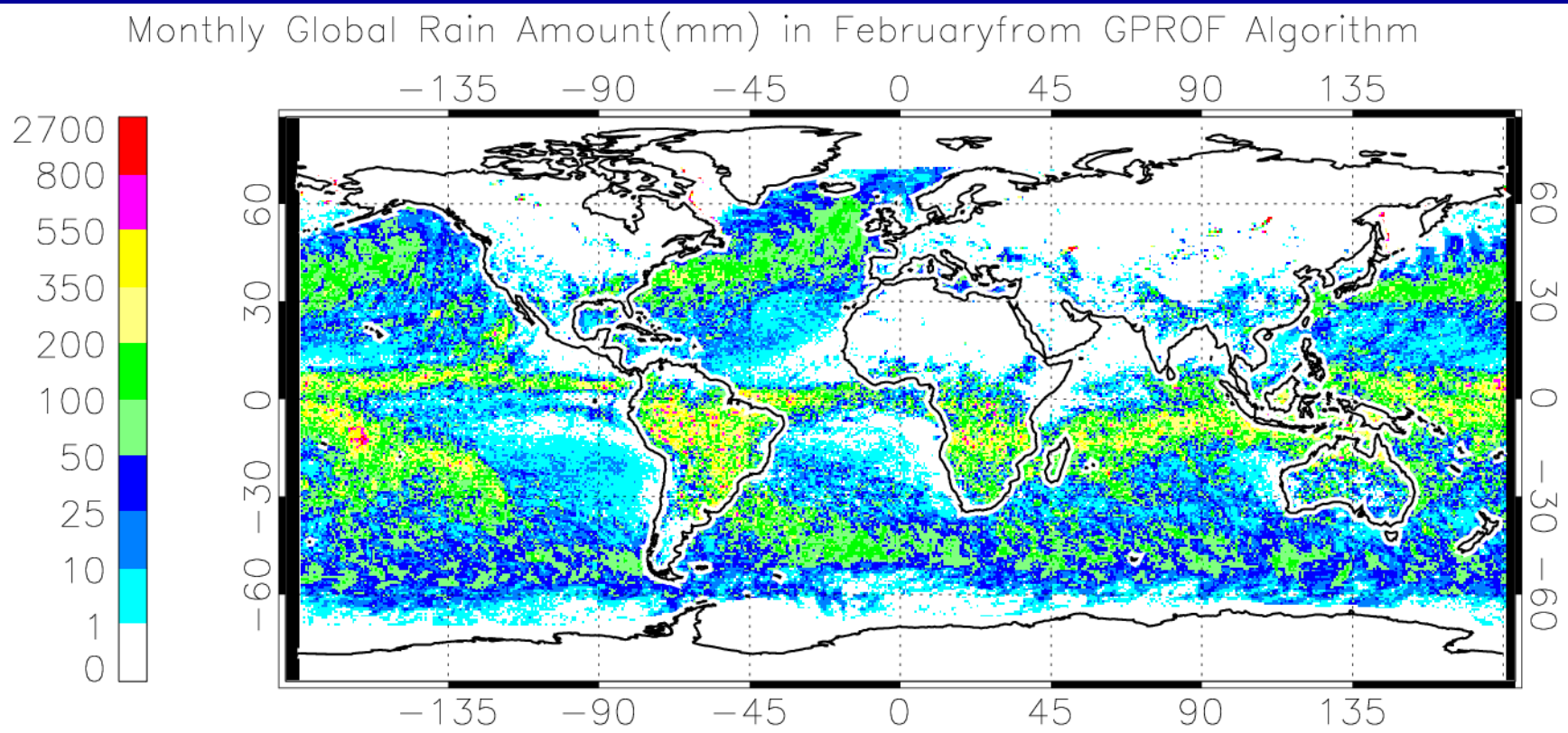
- UW-Madison FTP results are very similar to GPROF in low- to mid-latitudes.
- Substantially higher FTP poleward of extratropical storm tracks, relative to GPROF.
- High FTP at high latitudes broadly consistent with ship-based climatology.

Assessment of Global Monthly Precip

- Qualitative patterns over global oceans
- Quantitative comparisons with atoll totals (2.5 degree boxes centered on atolls)


Monthly Global Rain Amount(mm) in February from PETTY Algorithm
2700
800
550
350
200
100
50
25
10
1
0
−135 −90 −45 0 45 90 135
60 30 0 −30 −60
Monthly Global Rain Amount(mm) in Februaryfrom GPROF Algorithm
3B43 combined accumulated rain amount(mm) in February


Monthly Global Rain Amount(mm) in February from PETTY Algorithm
2700
800
550
350
200
100
50
25
10
1
0
−135
−90
−45
0
45
90
135
60
30
0
−30
−60


Monthly Global Rain Amount(mm) in Februaryfrom GPROF Algorithm
2700
800
550
350
200
100
50
25
10
1
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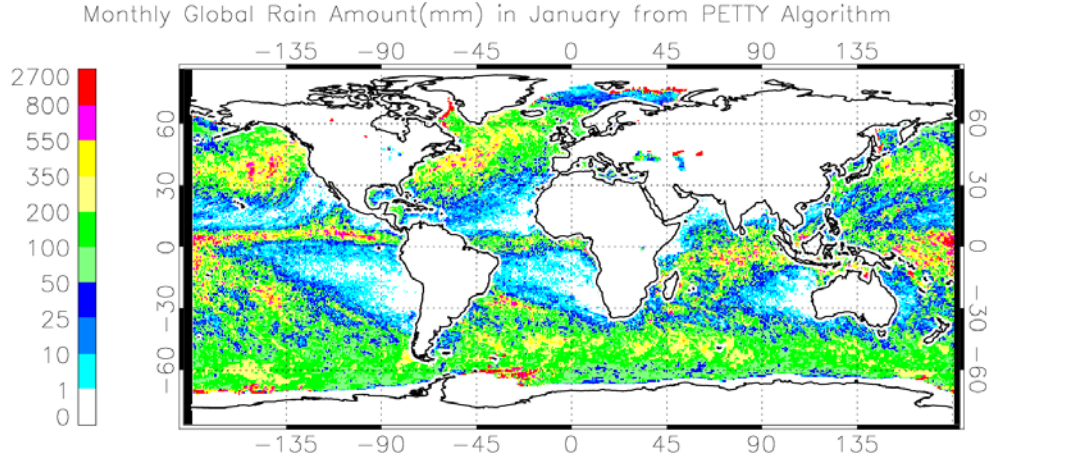
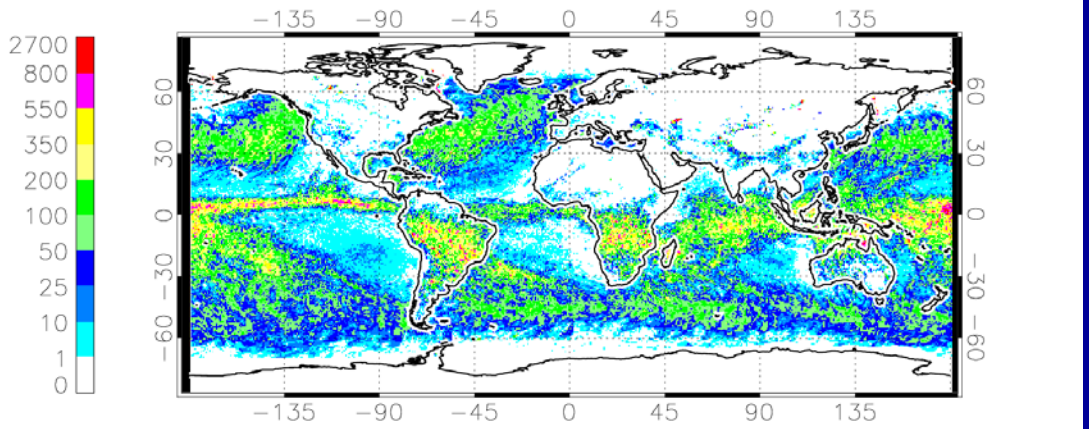
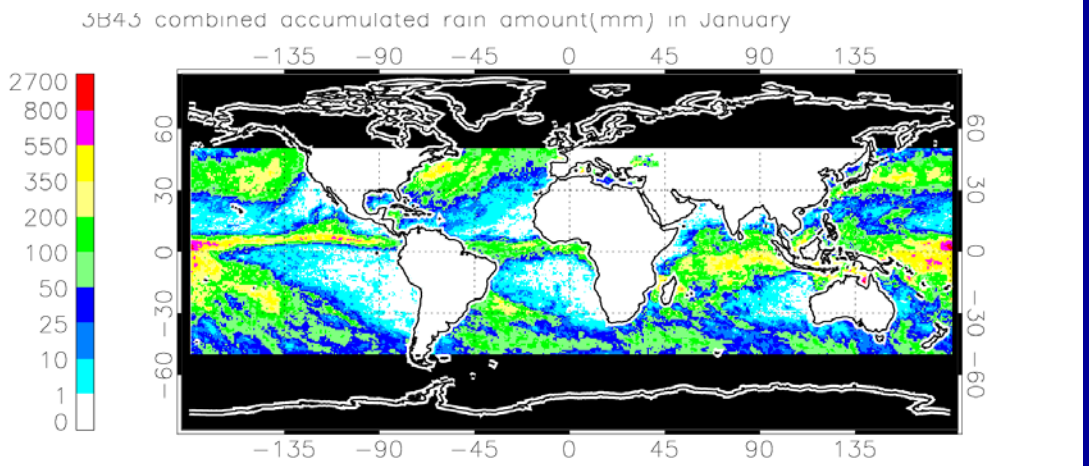
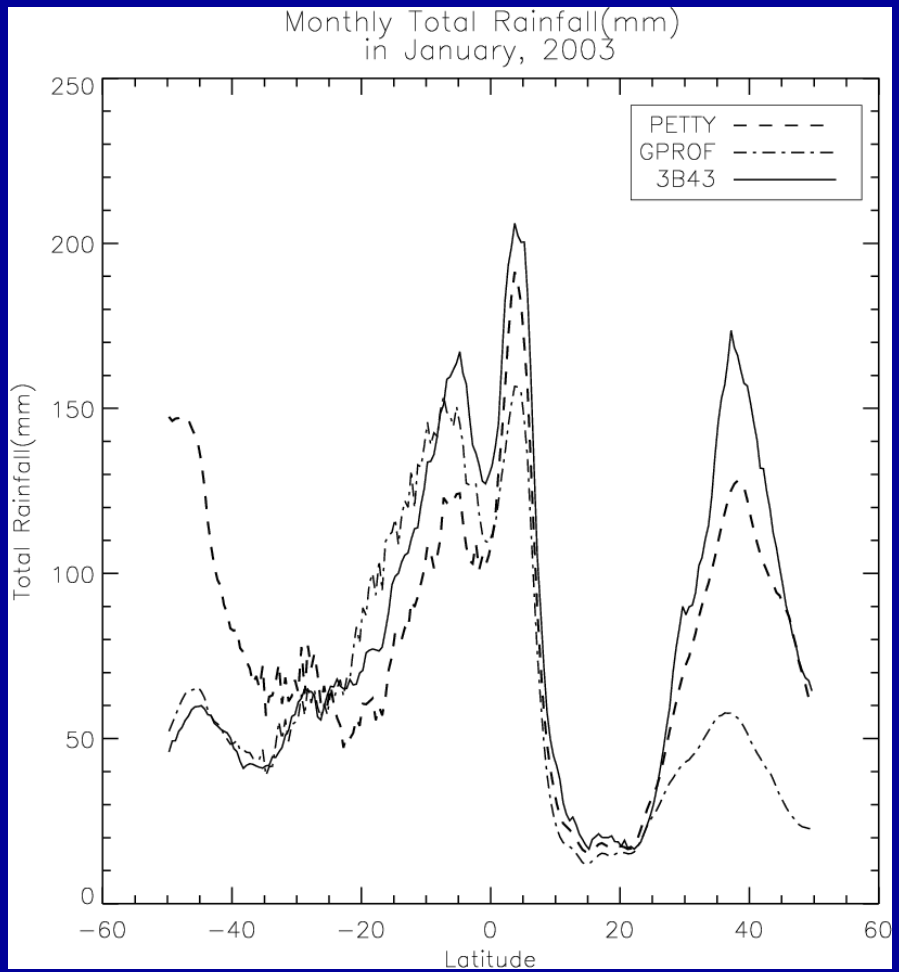
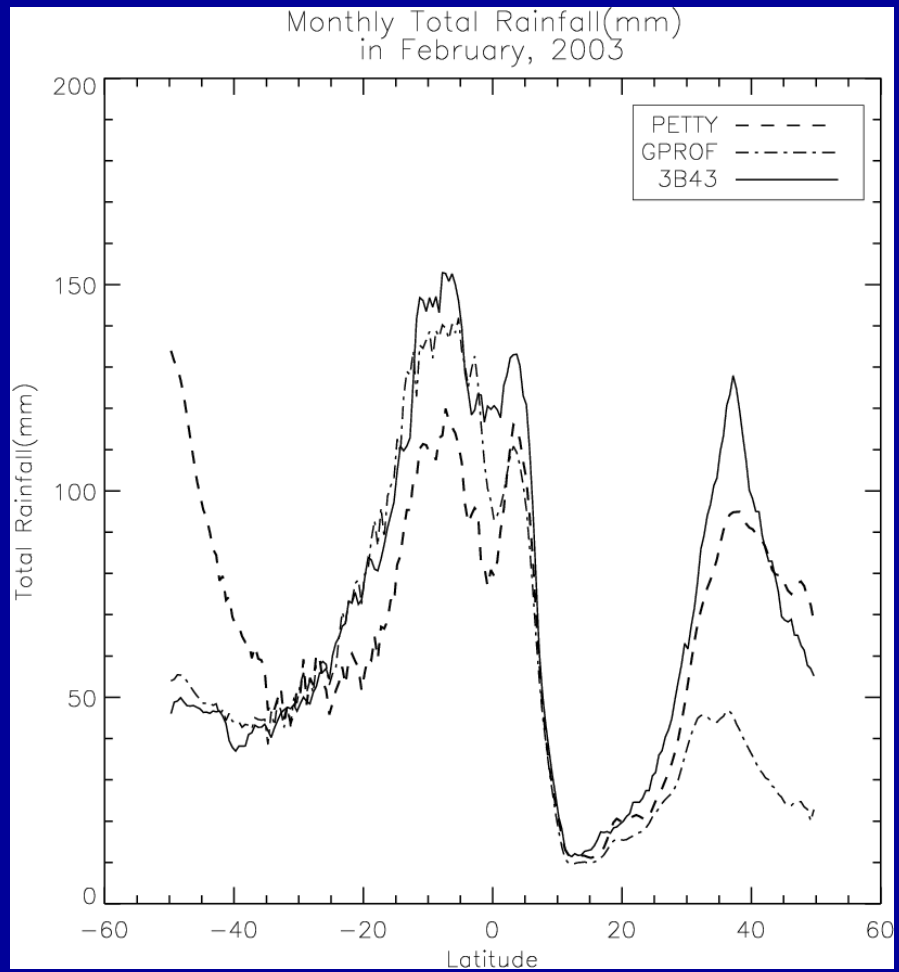
−90
−45
0
45
90
135
60
30
0
−30
−60


Monthly Global Rain Amount(mm) in January from PETTY Algorithm
2700
800
550
350
200
100
50
25
10
1
0
−135 −90 −45 0 45 90 135
60 30 0 −30 −60

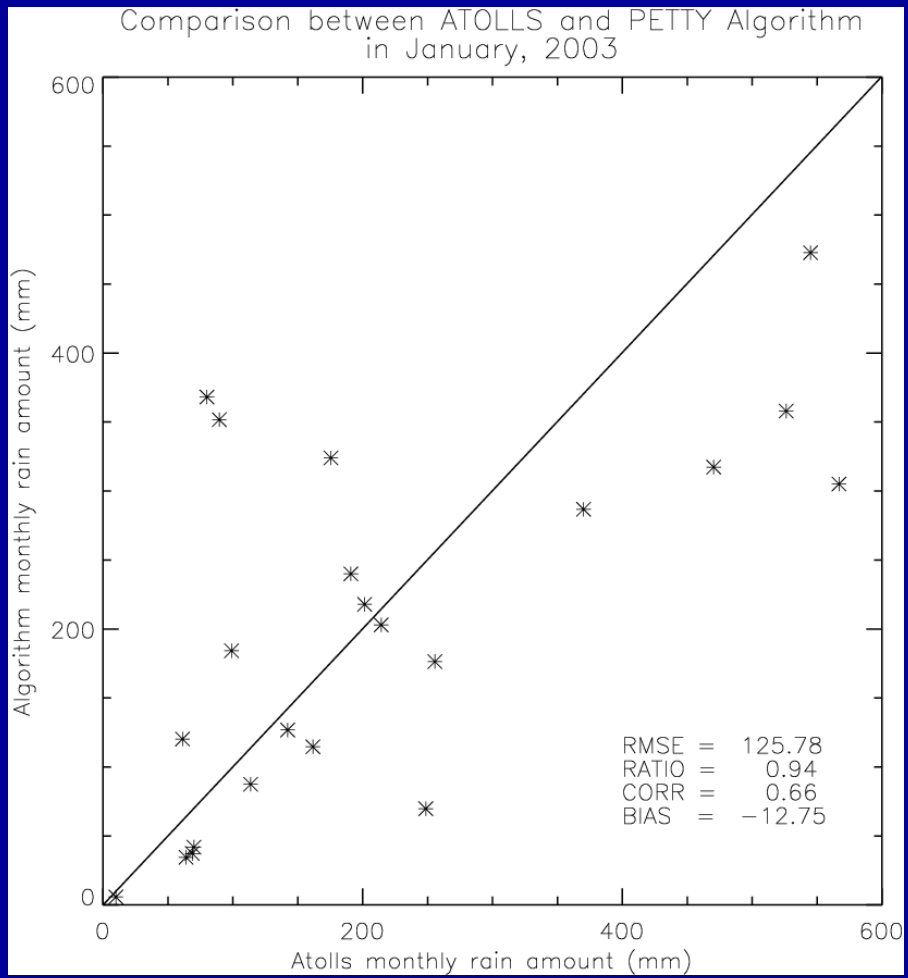

Monthly Global Rain Amount(mm) in Januaryfrom GPROF Algorithm
2700
800
550
350
200
100
50
25
10
1
0
−135 −90 −45 0 45 90 135
60 30 0 −30 −60

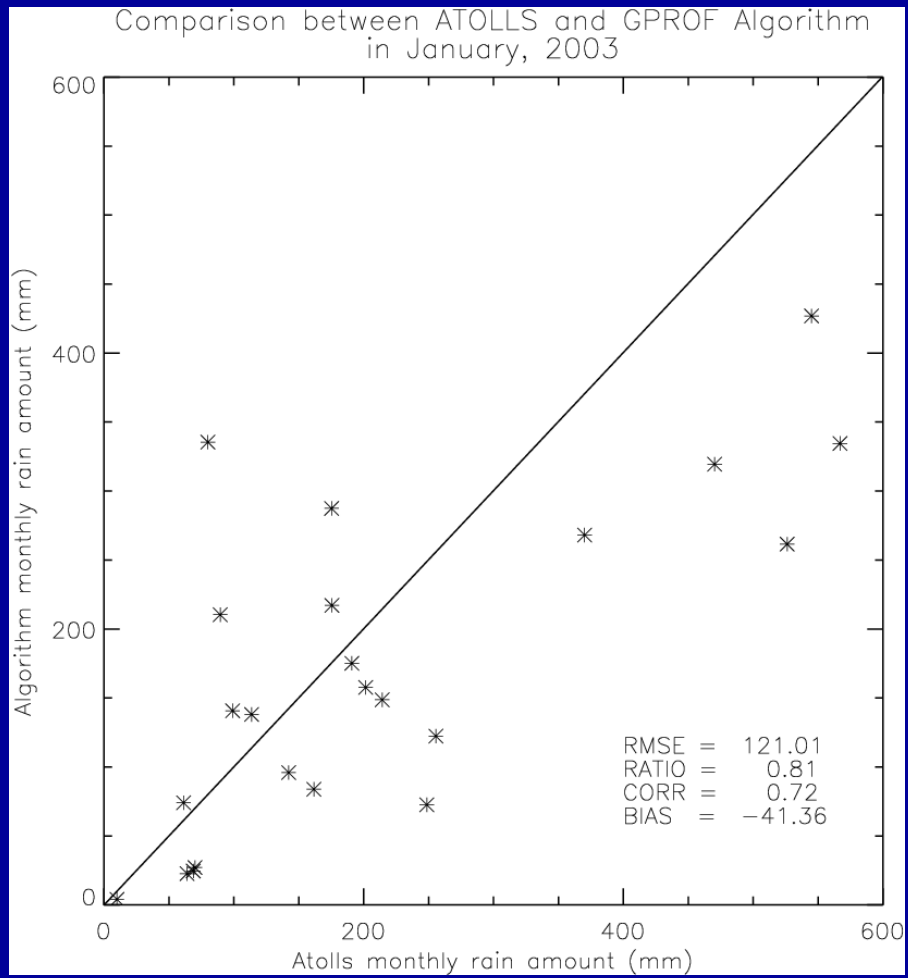

3B43 combined accumulated rain amount(mm) in January
2700
800
550
350
200
100
50
25
10
1
0
−135 −90 −45 0 45 90 135
60 30 0 −30 −60


Monthly Total Rainfall(mm)
in January, 2003
PETTY
GPROF
3B43
Total Rainfall(mm)
Latitude
250
200
150
100
50
0
−60
−40
−20
0
20
40
60


Monthly Total Rainfall(mm)
in February, 2003
PETTY
GPROF
3B43
Total Rainfall(mm)
Latitude
200
150
100
50
0
−60
−40
−20
0
20
40
60

Comparisons with Monthly Atoll Totals





Summary – Preliminary Assessment of Monthly Totals (J/F 2003 only)

- Results extremely similar to GPROF at low and middle latitudes!
- Comparisons with atolls yield comparable results for UWM and GPROF algorithms
  - Slightly lower correlation for UWM
  - Slightly “better” bias for UWM
- Much higher totals at high latitudes for UWM.

Unanswered Question

How reasonable are high latitude totals?

- If FTP is already reasonable, then reasonableness of totals depends only conditional mean precipitation rate.
- UWM algorithm yields approx. 140 mm/month at 50^{o}S and FTP=16%
  -> 1.2 mm/hr conditional mean *R*
  - Too high? Who knows? (No validation!)
  - If wrong, easily adjusted!
- REQUIRED: Systematic assessment of mean high-lat ocean precip amounts, using variety of independent (probably *indirect*) information.

Summary

- UWM algorithm performs comparably to GRPOF in low latitudes; seems to pick up high-latitude / cold-season precip more reliably.
- Absolute totals poleward of 50^{o} are suspiciously high, but can be easily corrected *if* evidence warrants.
- Above performance reflects less than one student-year of in-house cal/val effort since first (SSM/I) version appeared in early 1990s.
- Variable-threshold HSS method is proposed as a new technique for characterizing precip algorithm performance.