Progress and Problems in Combining Global Satellite Precipitation Products and Surface Gauge Measurements: Focus on High Latitudes

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1. COMBINATION TECHNIQUES

a. Goal is high-quality, uniform, global, long-term, fine-scale time-space grid of precipitation estimates.

b. Current approaches to combining satellite data are:

- **NASA/NRL (Huffman/Turk): Eulerian time slices (all data falling in time/space grid box, intercalibrated):**
  - **GPCP (SG, pentad, 1DD); TRMM TMPA (3b42, 3b43, 3b42RT); NRL**
  - **robust to data variations**
- **NOAA (Joyce, Janowiak): Lagrangian time interpolation (morphing; also intercalibrated):**
  - **CMORPH, GSMAP**
  - **provides fine-time interval**

c. Combinations that incorporate gauge data surpass no-gauge products

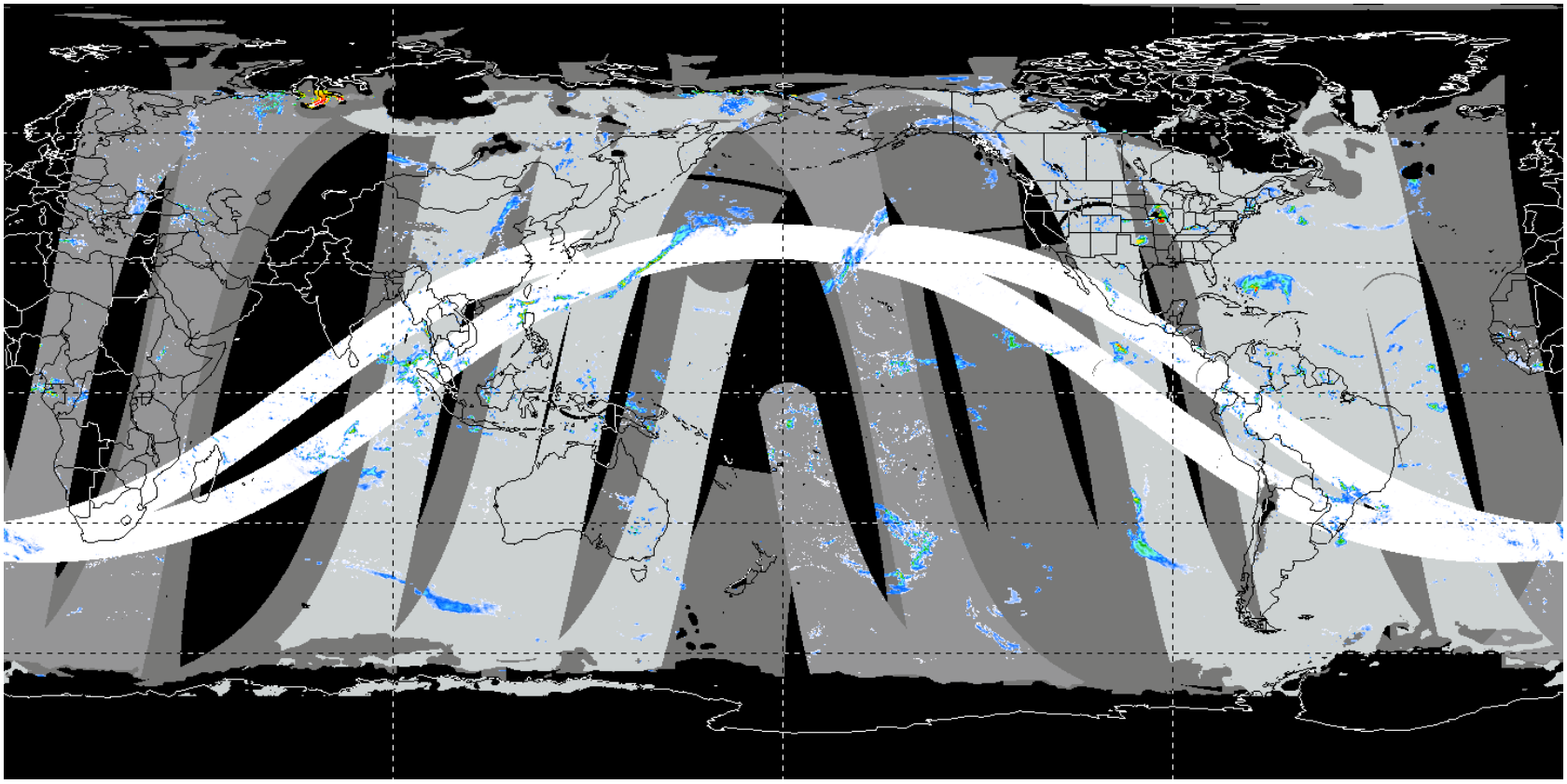
d. Current approaches to combining gauge data are:

- **Huffman (NASA): Large-area bias removal, inverse error weighting in monthly fields; scale shorter-interval estimates to sum to monthly estimates (GPCP; TMPA)**
- **Xie (NOAA): Cressman analysis in daily fields; scale shorter-interval estimates to sum to daily estimates (for densely gauged regions)**

EXAMPLE OF RESULTS FROM TRMM TMPA Scheme
(TRMM Multi-satellite Precipitation Analysis)

Merged microwave is approaching 80% coverage for 3-hour time slice

TMI - white SSMI - light gray AMSR - medium gray AMSU - dark gray



Microwave (mm/h) 00Z 25 May 2004

2. HIGH-LATITUDE/COLD SEASON INPUT DATA ISSUES

Combination results are dominated by limitations in input data

a. Note "cold/snowy" issues dominate in wintertime:

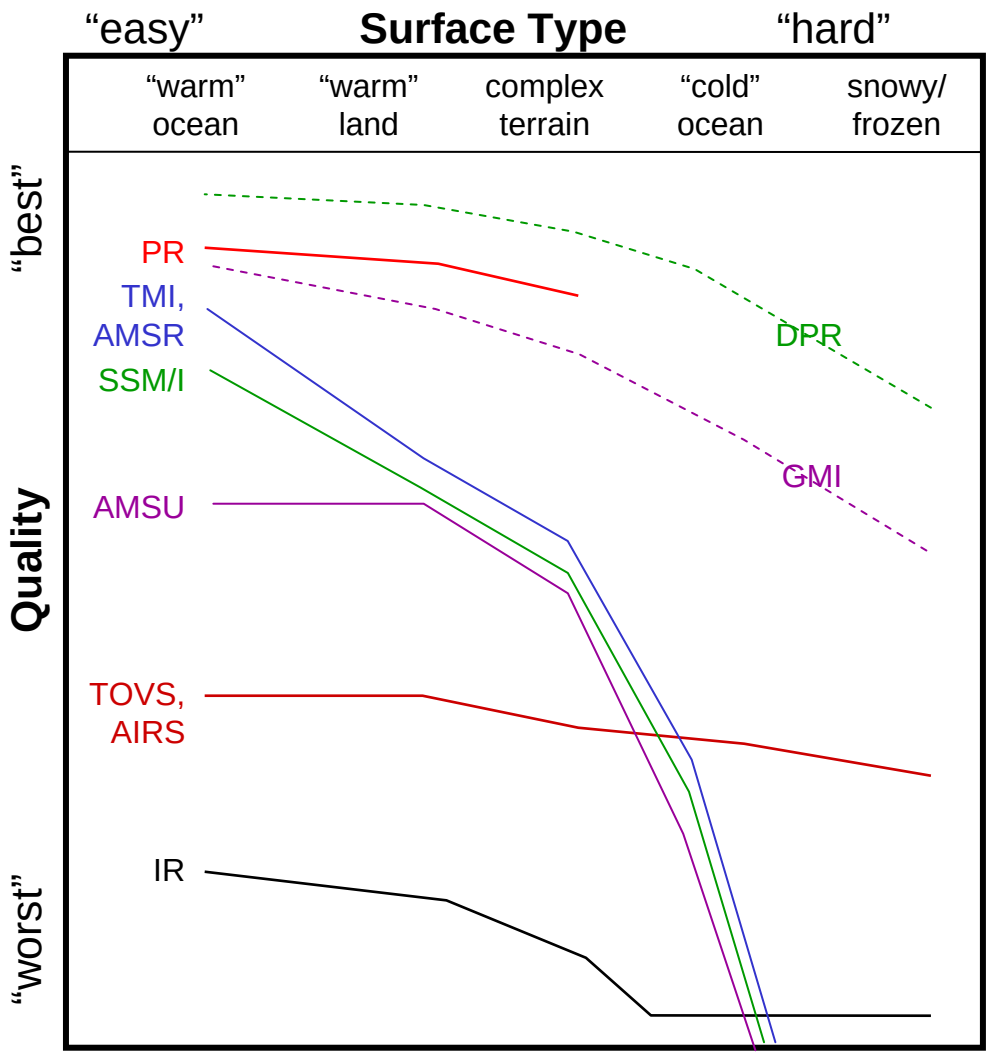
- **U.S., episodically to Gulf Coast;**
- **temperate mountains -- Rockies, Andes, Himalayas, Tibetan Plateau, Alps;**
- **Europe and Siberia.**

b. Remaining uncertainties about possible information content of various sensors:

- **sensing precipitation over ice, snow, & frozen surfaces;**
- **sensing light precipitation and/or precip in cold, dry environments.**

c. Estimates with longer records have lower quality -- leading to basic question is: What is "good enough" for operational global data?

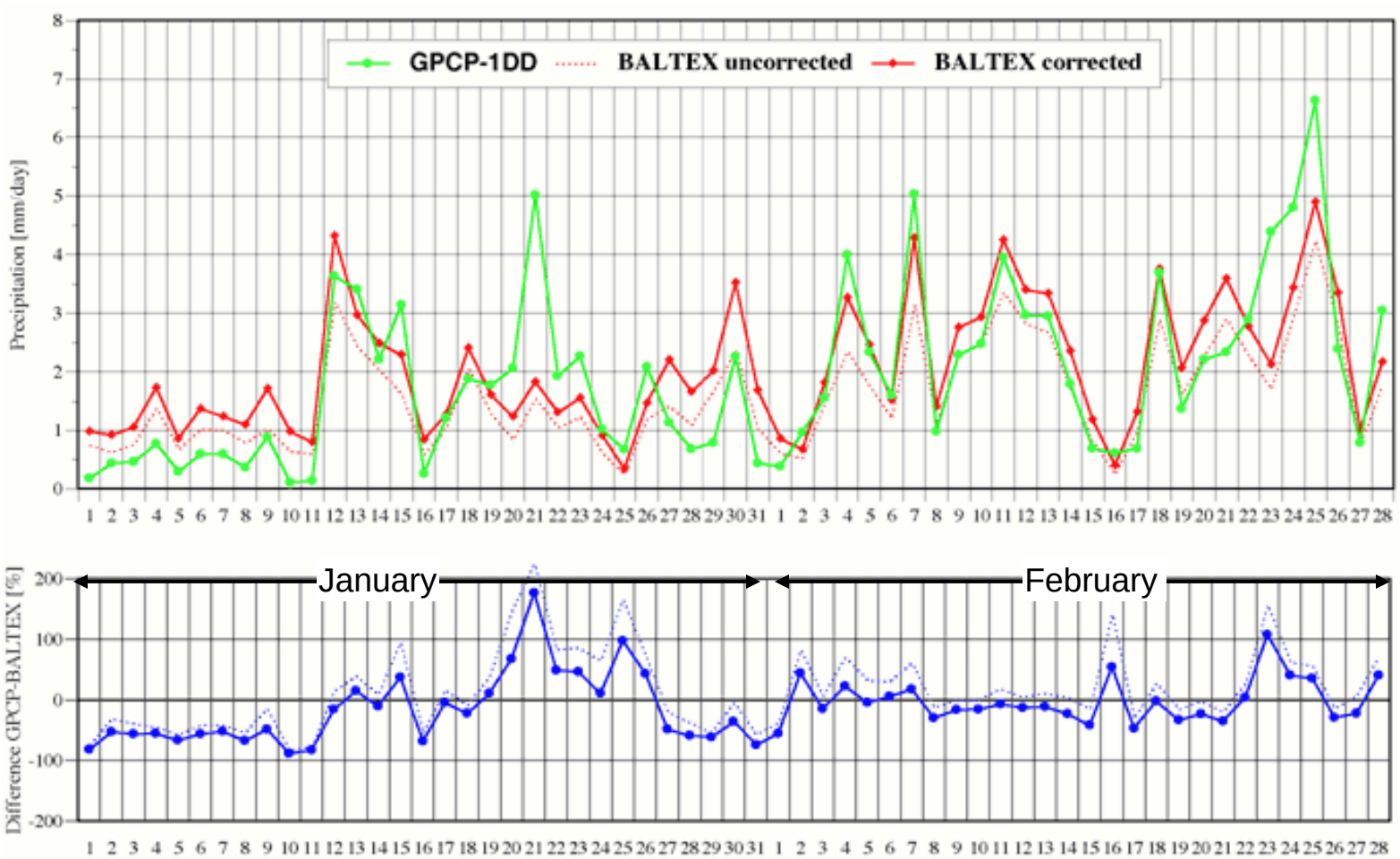
d. Error estimation in high latitudes is as challenging, or more so, as in tropics.



3. EXAMPLE OF HIGH-LATITUDE PRECIP COMBINATION

a. Comparisons of GPCP-1DD to BALTEX gauge analysis averaged over Baltic Sea drainage basin (Jan-Feb 1997)

- **monthly bias set by gauge calibration**
- **day-to-day variation driven by rescaled TOVS sounding-based estimates**



4. HIGH-LATITUDE DATA QUALITY

a. Chris Kidd -- British Isles, zonal profiles of precipitation occurrence over ocean

- "standard" SSMI schemes
- compared to gauges (British Isles) and COADS ship records
- in 2 studies, detectability thresholds cause satellites to miss up to 80% of occurrences, amounting up to 50% of accumulation (British Isles)

b. Christian Klepp -- Arctic (2001, 2005)

- standard SSMI schemes, GPCP 1DD
- compared to ships of opportunity, ECMWF, Bauer and Schlüssel (1993) SSMI algorithm for cases of intense post-frontal squalls in far North Atlantic
- these squalls are relatively frequent and mostly missed -- short-interval (1DD, pentad) give wrong patterns while monthly accumulations give wrong totals

c. Mark Serreze -- Arctic (2003, 2005)

- mostly GPCP monthly multi-satellite before gauge-adjustment step
- compared to gauges, including ice islands, and NCEP reanalysis
- better agreement in SSMI era and in summer
- generally low in Ob, Venisey, and Lena River basins
- variability tends to be low
- gauge adjustment is important

d. Christophe Genthon – Antarctic (2003)

- GPCP monthly SG
- compared EOFs to EOFs for NCEP/NCAR, NCEP2, LMDZ reanalyses
- results are much better in SSMI era
- variability tends to be "different" in mostly-SSM/I bands 40-50°N/S

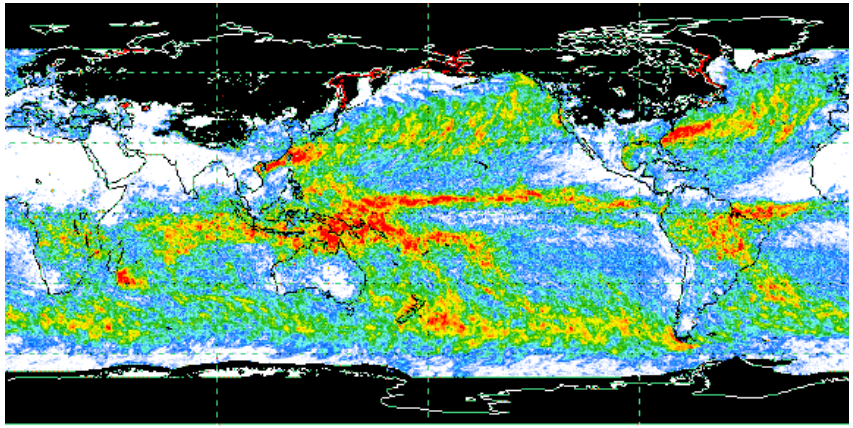
PIXEL-LEVEL ISSUES

Maps of pixel-level fractional occurrence of precipitation for AMSR, SSMI, and AMSU illustrate different:

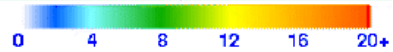
- **masks to avoid artifacts,**
- **degrees of success in pixel-by-pixel rejection of artifacts,**
- **sensitivities to light precipitation**

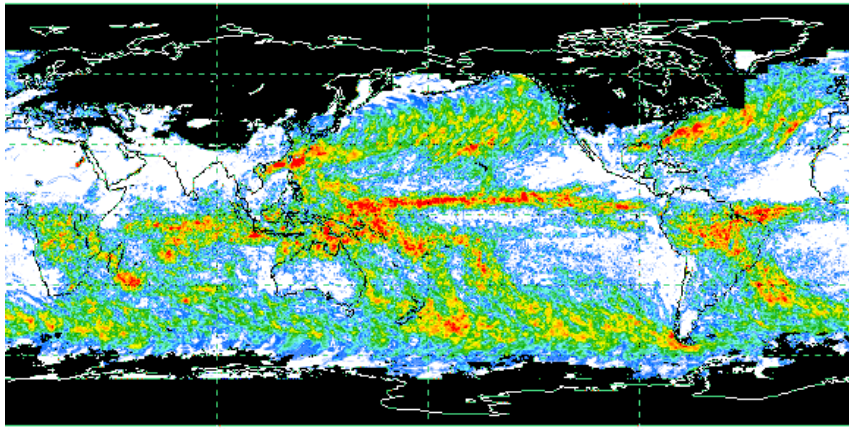
Fractional coverage issue is most noticeable in oceanic subtropical highs:

- **Can not intercalibrate rain that does not exist !**
- **But -- if there are "too many" rain events, smallest ones can always be set to zero.**

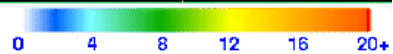


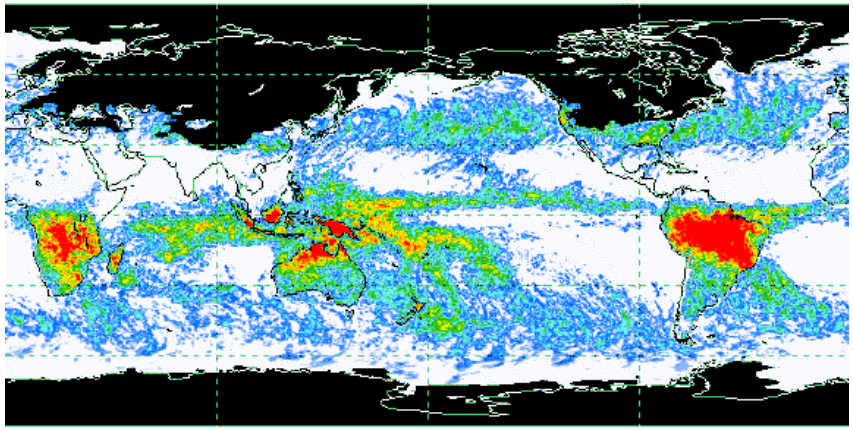
AMSR (% precip) Feb 2004



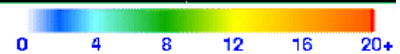


SSM/I F13 (% precip) Feb 2004





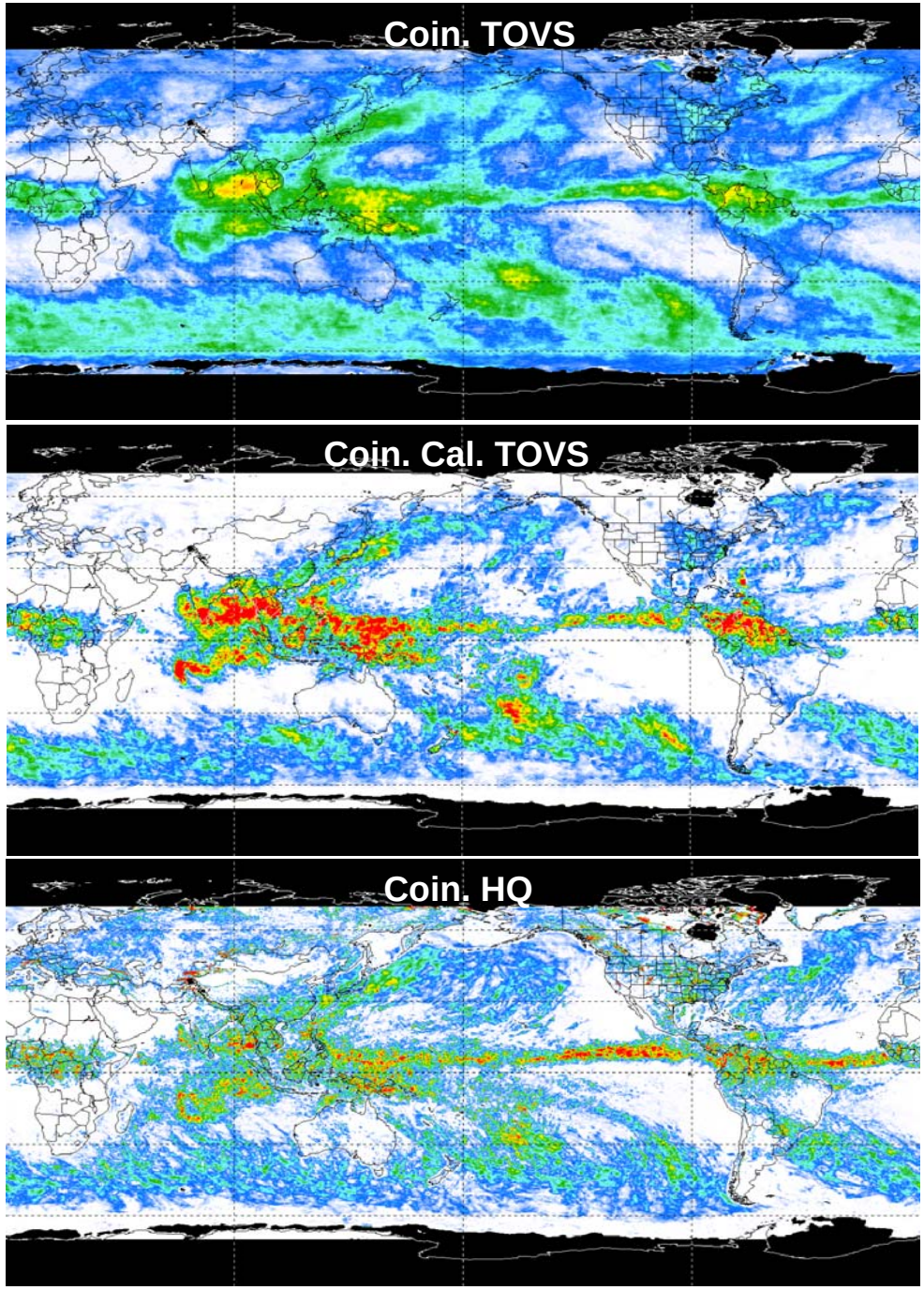
AMSU NOAA-L (% precip) Feb 2004



HIGH-LATITUDE FIRST ROUND WITH TOVS

5 ocean, 1 land histogram match against "HQ" merged microwave for May 2004 qualitatively corrects coverage and rate factors:

- **coincident sampling is reasonable**
- **larger coverage by high values likely results from very stubby tail in TOVS precipitation histogram**
- **fall-off in HQ at high latitudes is forced into calibrated TOVS; this needs to be examined**



May 2004 (mm/d)

5. HIGH-LATITUDE / COLD SEASON NEEDS

a. Additional sources of high-quality input data

b. Improved retrieval schemes using legacy, current, & new input data sources

- liquid equivalent
- precipitation type
- error estimates

c. High-quality data sources for broad-scale high-lat calibration & validation

- fine-scale for detailed algorithm development
- long-term for examining climatological statistics
- CloudSat data very useful; GPM DPR is coming; possibly SNOWSAT mission
- gauge data continue to be problematic

d. Continued development of both current and long-term data records

e. Agreement on scalable, near-equal-area global grid

- re-gridding can damage fine-scale precipitation statistics

f. Improved combination approaches that

- shift out inputs as they degrade or terminate -- but
- without damaging higher-order statistics

Backup Slides

TMPA 3-Hourly and Monthly

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, **8**(1), 38-55.

GPCP Monthly

Adler, R. F., G. J. Huffman, A. Chang, R. Ferraro, P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, and P. Arkin, 2003: The version 2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (1979-present). *J. Hydrometeor*., **4**, 1147-1167.

GPCP Pentad

Xie, P., J. E. Janowiak, P. A. Arkin, R. Adler, A. Gruber, R. Ferraro, G. G. Huffman, and S. Curtis, 2003: GPCP pentad precipitation analyses: an experimental data set based on gauge observations and satellite estimates. *J. Climate*, **16**, 2197-2214.

GPCP Daily

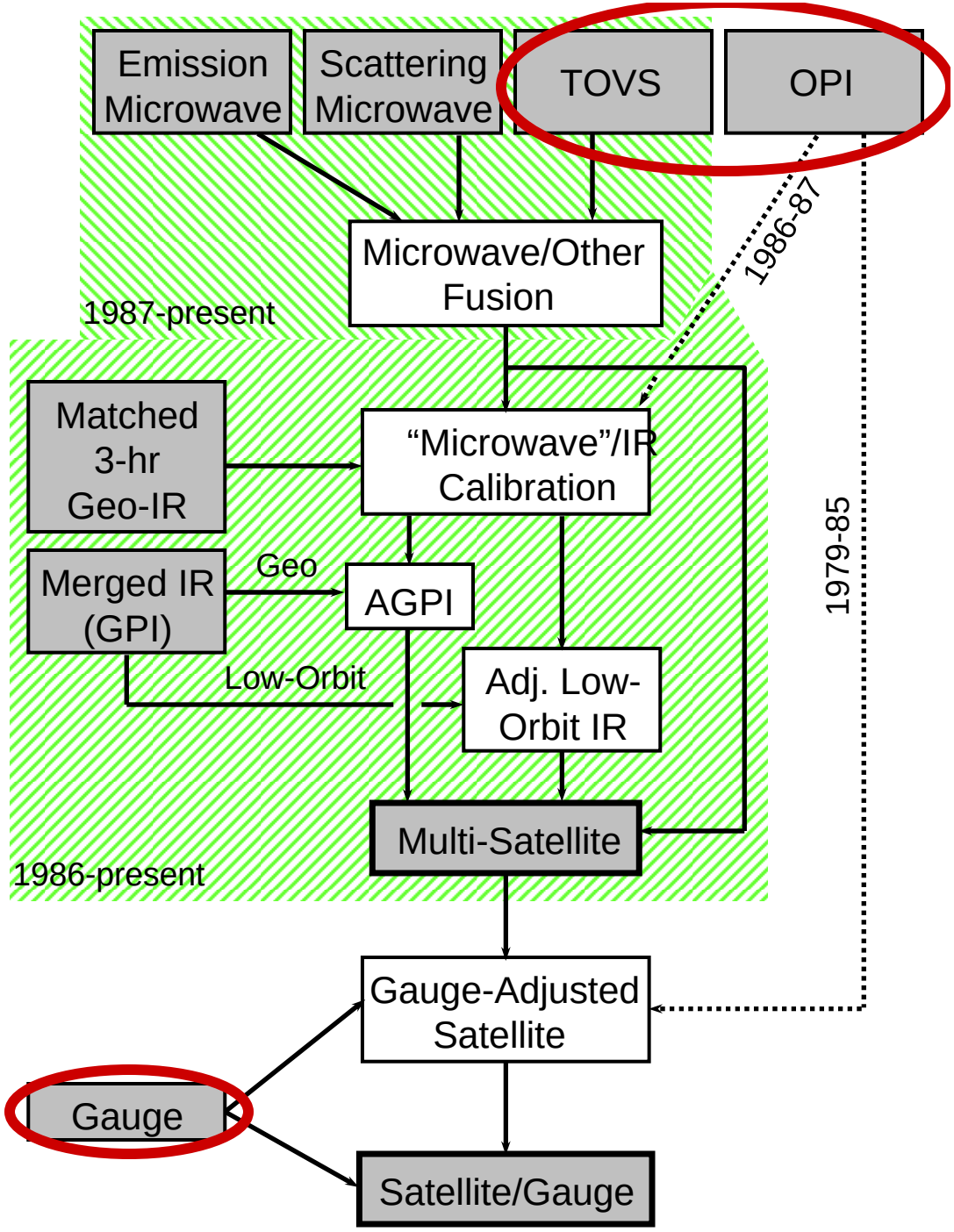
Huffman, G.J., R.F. Adler, M. Morrissey, D.T. Bolvin, S. Curtis, R. Joyce, B McGavock, J. Susskind, 2001: Global Precipitation at One-Degree Daily Resolution from Multi-Satellite Observations. *J. Hydrometeor.,* **2**(1), 36-50.

HIGH-LATITUDE DATA <u>Sources</u>

Accurate input data are less plentiful at high latitudes

Data Set	Advantages, Disadvantages
Window-channel microwave	long record detectability problems; interference by surface ice/snow
Current NESDIS AMSU-B	operational footprint size; interference by surface ice/snow
NOAA/CPC OLR Precip Index (OPI)	long record; apparent sensitivity at all latitudes short development history; problems in early data record; need for independent climatology; problems in application for extremes
Gauge	“ground truth”; long record severe, location-dependent undercatch; sparse spatial sampling
NASA/SRT TOVS and AIRS; NESDIS ATOVS	long record; apparent sensitivity at all latitudes short development history; problems in early TOVS data record; high fractional coverage/low rain rate; footprint size
High-frequency microwave	reasonable retrievals over surface ice/snow short record; short development history

INTRODUCTION <u>Version 2</u>
<u>Monthly Satellite-Gauge (SG)</u>



- <u>High-latitude</u> and cold-season precip estimates provided by <u>gauge, TOVS, OPI</u>

SSMI–TOVS Merger, V.2 GPCP SG

Gauge-Adjusted TOVS

Ratio-Adjusted TOVS# [ratio set to 1 at Iceland latitude bands]

Average of SSMI & TOVS, if SSMI exists
Zonal Average Ratio-Adjusted TOVS+, if no SSMI

SSMI, if SSMI exists
Zonal Average Ratio-Adjusted TOVS*, if no SSMI

Average of SSMI & TOVS, if SSMI exists
Zonal Average Ratio-Adjusted TOVS+, if no SSMI

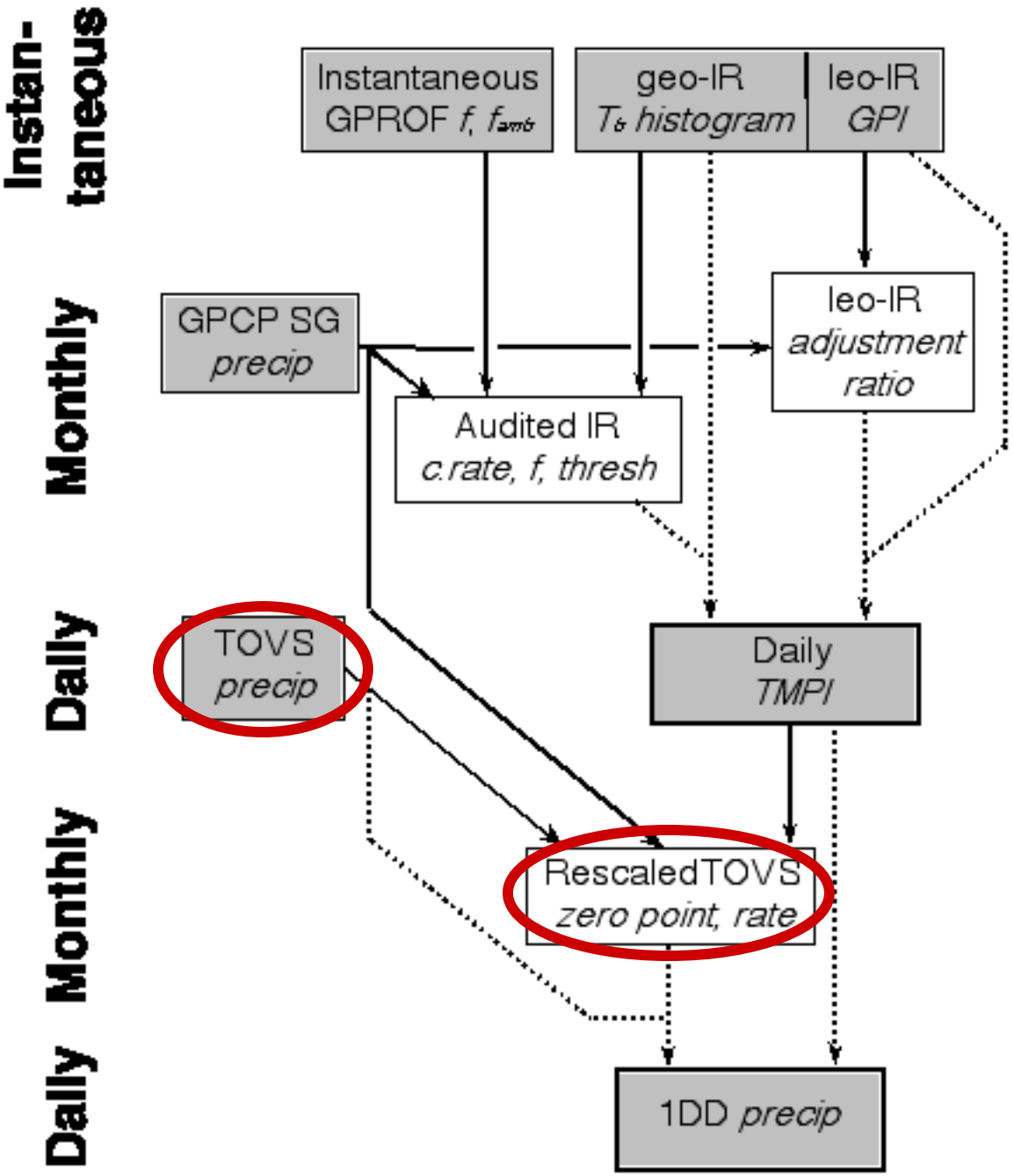
Ratio-Adjusted TOVS#

Gauge-Adjusted TOVS

Transition Zones

INTRODUCTION One-Degree Daily (1DD)

- High-latitude and cold-season precip estimates provided by TOVS, scaled by SG



INTRODUCTION Getting to the Future

Current

- Monthly estimates from selected data sets
- Pentad and daily scaled to (approx.) add up to the monthly

Planned

- Use "all" available data to get fine time/space resolution estimates
- Rescale fine-scale to account for monthly input data (gauges)
- System needs to gracefully degrade/improve as satellite complement evolves

Design choices

- Satellite data are calibrated to a single standard
- Data are combined sequentially; less-certain data are used to fill voids in more-certain data
- Combinations done after calibration

We need much-improved precip algorithms at high latitudes and for cold seasons

HIGH-LATITUDE First Round With TOVS

The NASA/SRT TOVS product has high fractional coverage and low rates.

We start out applying probability matching to coincident data for May 2004:

- using TMI, the correction was partitioned into 1 ocean and 1 land histogram
  - not satisfactory, as expected

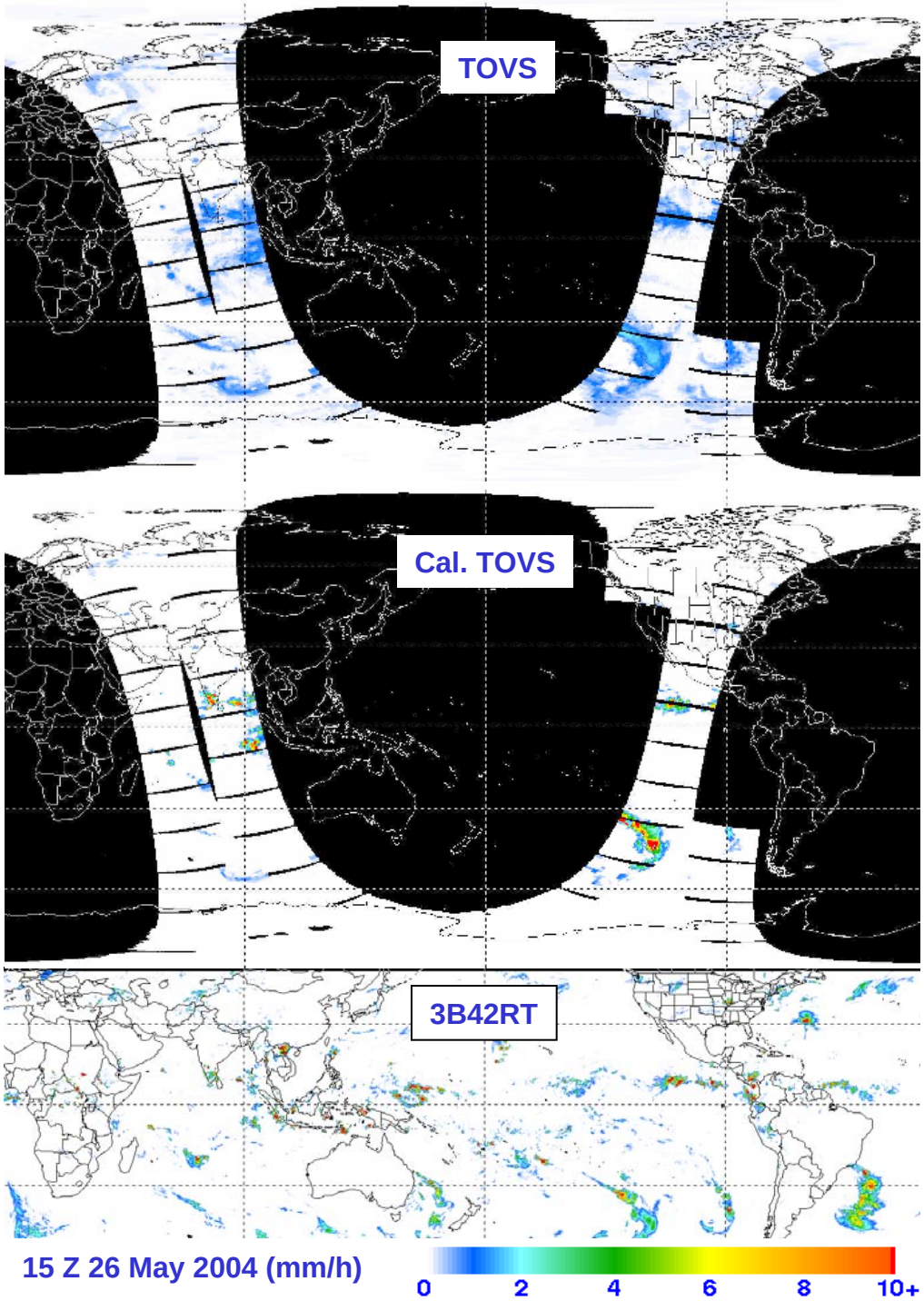
- using TMI, the correction was partitioned into 5 ocean and 1 land histogram
  - ocean zones are: 40-30°S, 30-10°S, 10°S-N, 10-30°N, 30-40°N
  - fairly successful within the TMI domain, but gave unreasonably high values in the Southern Ocean

- using the HQ (inter-calibrated to TMI), the correction is being partitioned into 5 ocean and 1 land histogram
  - ocean zones are: 45-20°S, 20°S-4°N, 4-9°N, 9-40°N, 40-55°N
  - we might move to 7 ocean bands for better match-ups
  - we must also examine the details over land

HIGH-LATITUDE <u>First Round with TOVS</u> (cont.)

Choosing a particular 3-hourly time, the calibrated TOVS is markedly closer to the corresponding 3B42RT than the original.

- The bands of “missing” are a feature of the processing.



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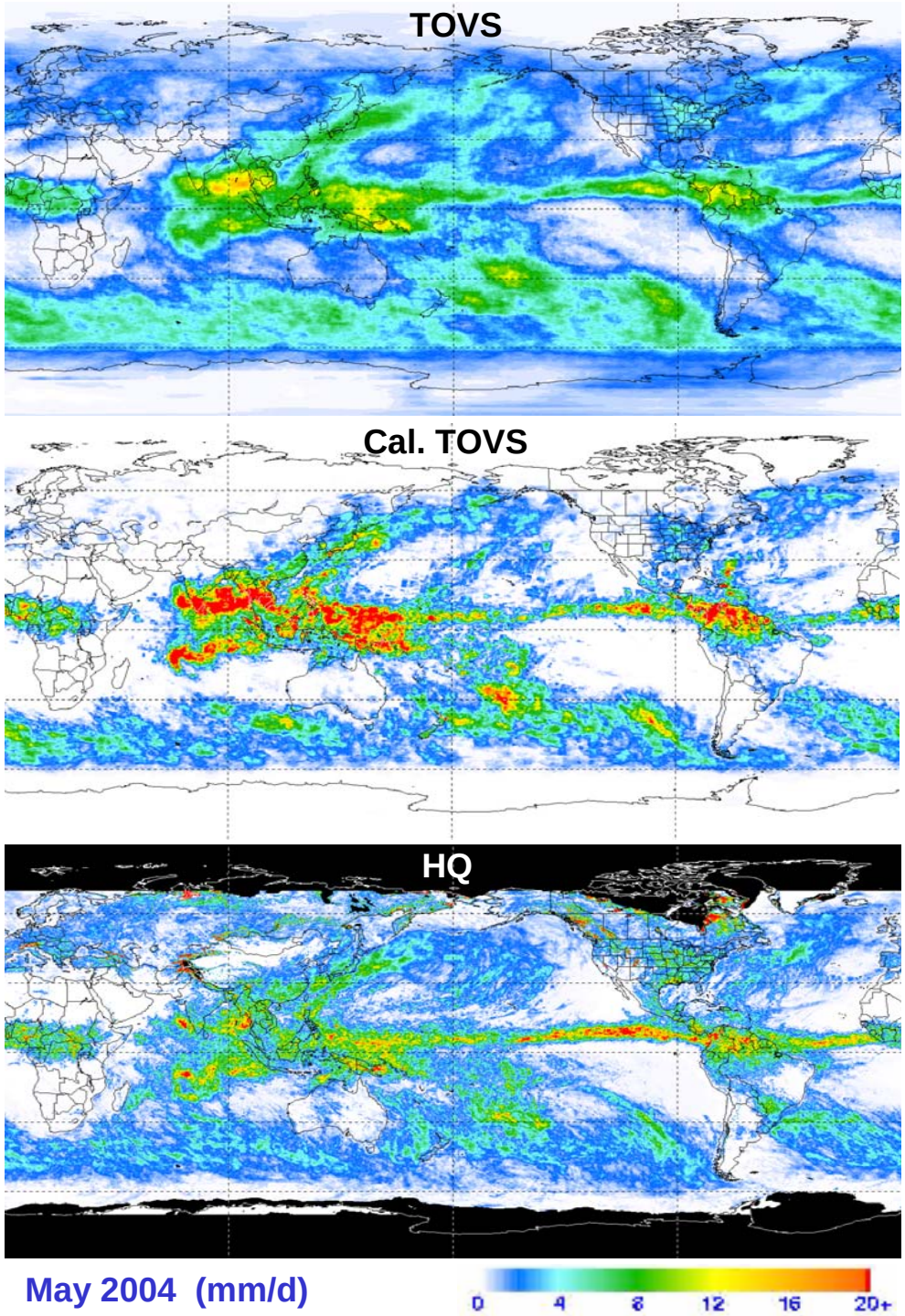
The 5 ocean, 1 land histogram match against the “HQ” merged microwave for May 2004 qualitatively corrects the coverage and rate issues.

- these are “full”, non-coincident maps
- the larger coverage by high values perhaps results from a very stubby tail to the TOVS precip histogram
- the fall-off in the HQ at high latitudes is forced into the cal. TOVS; this needs to be examined