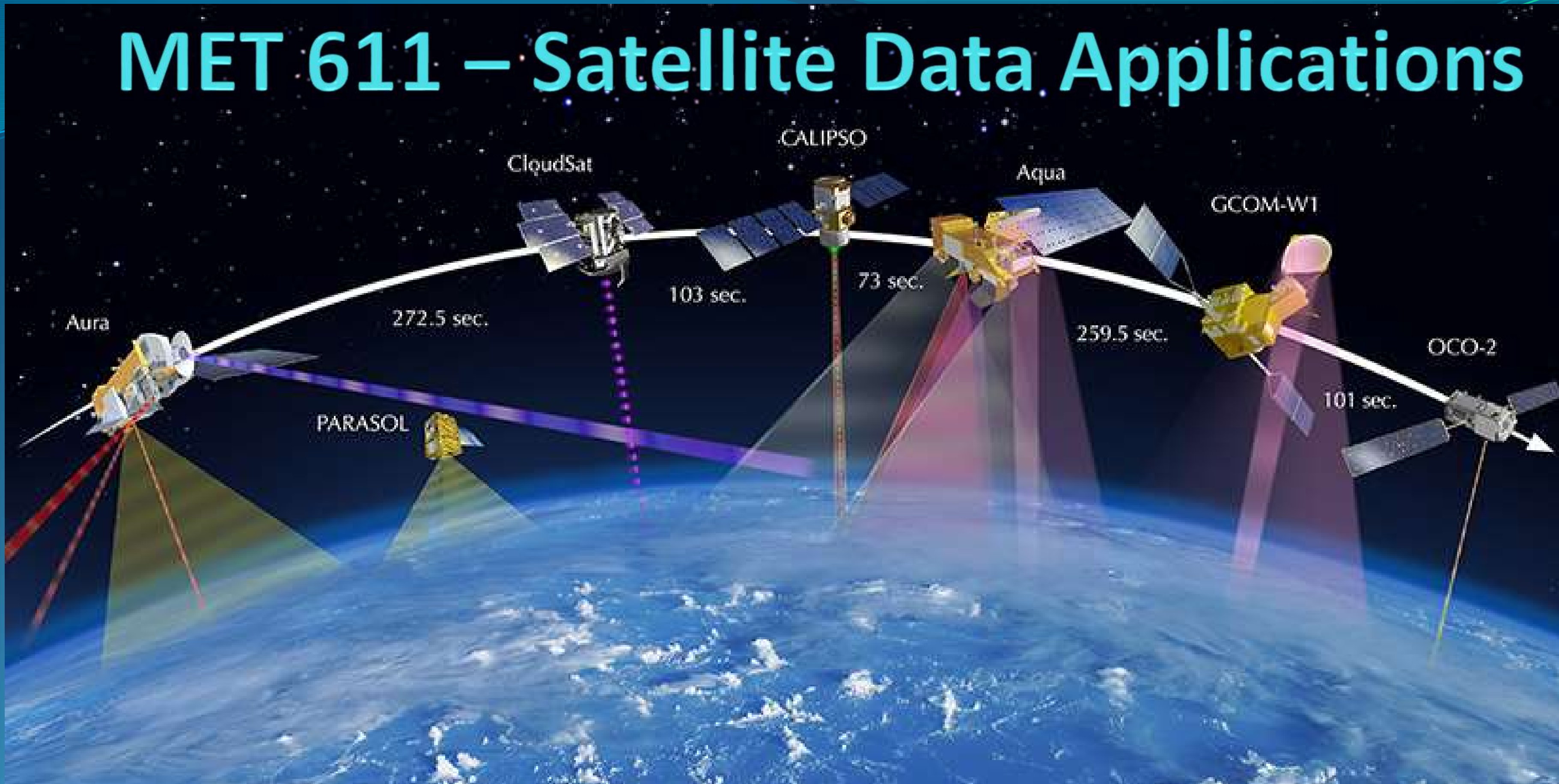
MET 611 – Satellite Data Applications



GPCP Continued – V3

Jennifer D. S. Griswold

High Latitude/Cold Season Data Issues

- **Besides the classic polar regions, this issue dominates in the wintertime**
  - U.S., episodically to the Gulf Coast
  - "temperate" mountains – Rockies, Andes, Himalayas, Tibetan Plateau, Alps
  - Europe and Siberia
- **Still uncertain about the possible information content of the various sensors:**
  - sensing precip over ice, snow, frozen surface
  - sensing light precip (everywhere) and/or precip in a cold, dry environment
- **Need to choose the best data sources for calibration and validation.**
  - GPM DPR will eventually play a key role, but what to use in the meantime?
  - It is critical to interact with high-latitude researchers on surface precipitation data.
- **Lower quality estimates tend to have longer periods of record; what is "good enough" for operational global data?**
- **Error estimation in high latitudes is at least as challenging as in the tropics.**
- **Key GPCP goals**
  - devise a quality globally complete, fine-scale precipitation algorithm system
  - provide estimates for a substantial part of the available satellite record

High-Latitude Data Sources

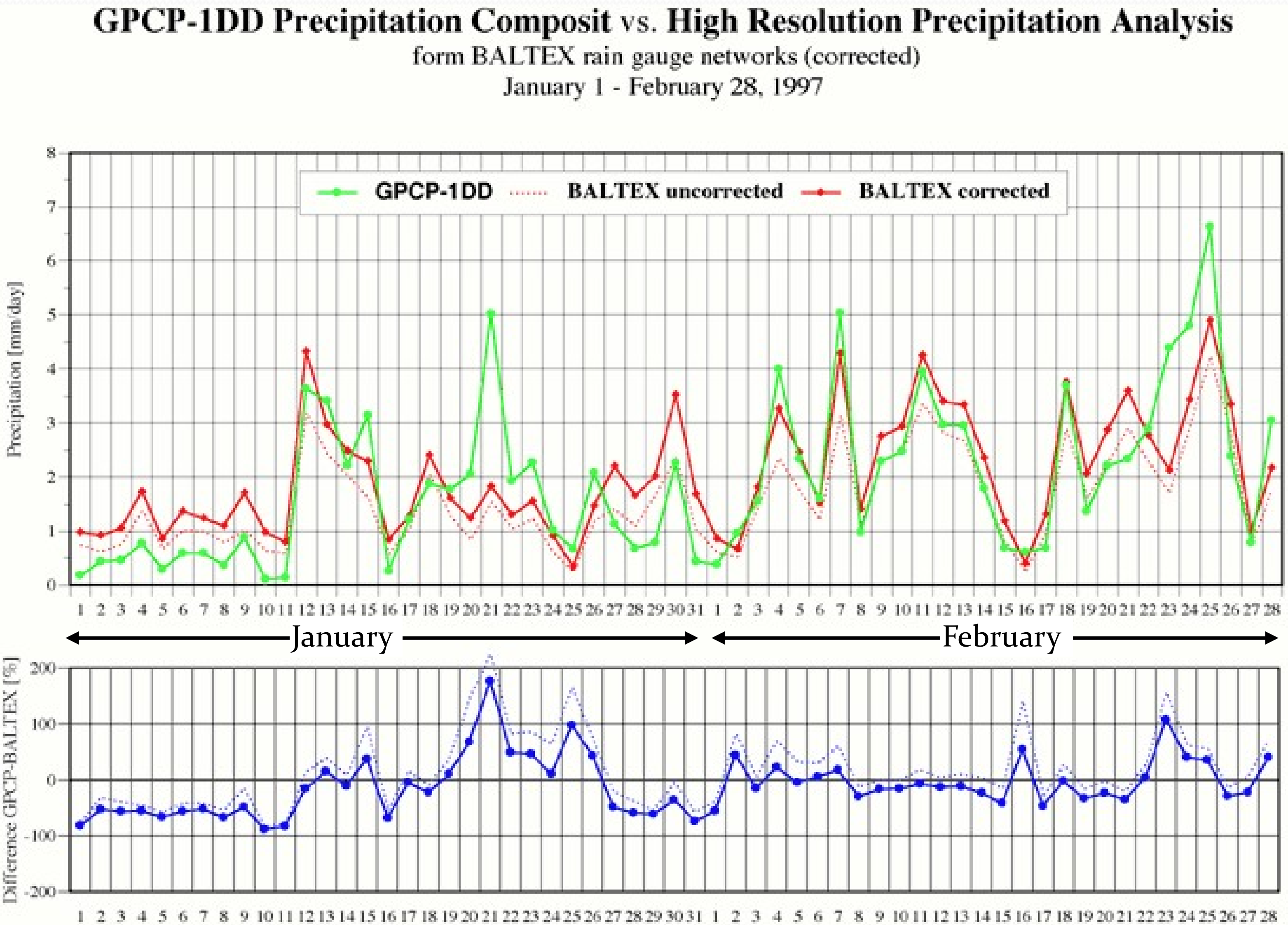
- Accurate input data are less plentiful at high latitudes

Less useful → More useful

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

High-Latitude Data Quality

Comparisons of 1DD to BALTEX gauge analysis averaged over Baltic Sea drainage basin



Lessons Learned

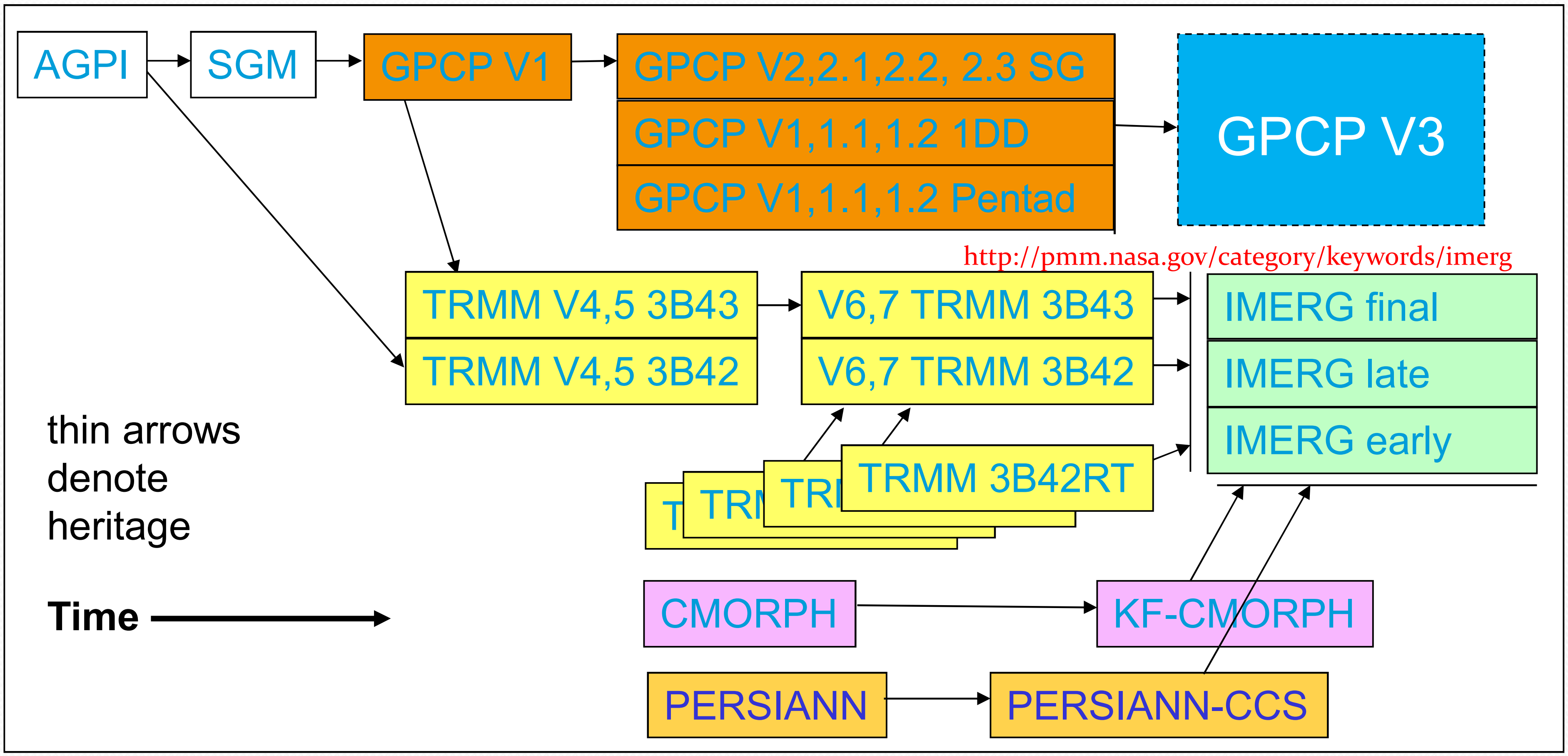
- **Community now recognizes two styles of precipitation data sets**
  - **High Resolution Precipitation Product (HRPP)**
    - focus on "best" instantaneous answer TMPA, IMERG, CMORPH, PERSIANN, GSMap, …
  - **Climate Data Record (CDR)**
    - Focus of homogeneity
- **GPCP follows CDR standards**
  - GPCP Version 2 now in the NOAA CDR program
- **User do analyses not originally imagined by the creators**
  - **Extremes** - Analysis schemes in current GPCP algorithms don't focus on preserving extremes
  - **Intermediate Products** – Originally released to show processing steps, but getting used for science.

Lesson Learned – Users Want new things!!

- **Precipitation Phase (Liquid/Solid)**
  - Current state of the art is a diagnostic using reanalysis T and R.H.
- **File Formats**
  - Heritage binary format seen as unfriendly (as is HDF!)
  - Non-expert users tent to use off-the-shelf applications
  - May of these have highly restrictive set of formats for inputting data
  - NetCDF, WorldTFF, KMZ, KML, text, CSV, shapefile-average
- **File Services**
  - area/parameter subsetting,data rods, WMS, GDS, THREDDS, ….
- **"Rapid" availability of data desired**
- **All this raise the bar for introducing a "modern" data set**
  - Archive centers have mostly taken the role of providing formats and services.

VERSION 3!!!!

Heritage → Version 3



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
- **Much-improved precipitation algorithms are needed at high latitudes and for cold seasons**

GPCP Version 3

- **New GPCP Version 3 will have:**
  - **Monthly 0.5 deg Resolution**
    - 1979-present
    - GPROF microwave algorithm applies to SSMI, SSMIS data as satellite calibrator
  - **Daily 0.5 deg Resolution**
    - 1998-present
    - possibility of extension to back in time
  - **Pentad 0.5 deg Resolution**
    - for whole 1979-present period
  - **3-hr 0.5 deg Resolution**
    - 1998-present
    - Match with ISCCP and SRB products

GPCP Product Plan con't

V3 still in development

- **REPROCESSING like MODIS "Collections"**
- **Continuation of current production**
  - heritage products at least for 4-5 years
- Minimization of data set time **boundaries** (or other) boundaries
- **Higher time and space resolutions**
  - 3 hr, 25 km for more recent part of the period (1998-present)
- New passive microwave algorithm (**GPROF,** Goddard profiling algorithm (GPROF) is the current operational rainfall algorithm for both TRMM TMI and AMSR-E, → More on GPROF later...
- **Integration** of high time/space resolution period with longer period with coarser time/space resolution
- Rain/snow discrimination (by temperature)

Goals for GPCP V3

- **In V3 they want to take advantage of**
  - advanced merger schemes
  - improved level 2 (swath) retrievals
    - GPROF
    - PERSIANN
    - IMERG
    - TRMM Composite Climatology
  - Fine time-space resolution
  - Stronger quality control and validation
  - Next-generation uncertainty estimates

- **But Still Maintain:**
  - Consistency among the various products
  - CDR standards

- **Datasets should be compatible with other water and energy cycle variables prepared by GDAP (GEWEX Data and Assessments Panel) members.**

Readiness and Issues for V3

- **Development and testing V3 now re-starting**
  - example products are generated, but slowed by problems with V2 and readiness of input data sets for V3

- **Required switch from SSMI to SSMIS also need to be solved for V3**
  - the GPROF algorithm for SSMIS is not in its final form

- **Geo-IR data (B1) not in final form**
  - Development being done with early version of B1 and GPROF for testing though final versions will likely require adjustments

- **Questions remain related to 3-hr input product and daily precipitation product to be used before 1998**

- **Initiation of production requires ~10 year data record minimum**
  - Completion of production requires consistent, full data record.
  - Completion dependent on reprocessing of GPROF SSMI/SSMIS

GPROF Algorithm Description

- **GPROF rainfall estimates** from SSM/I are used in the Global Precipitation Climatology Project (GPCP) merged rainfall product [Huffman et al., 1997].

- **GPROF retrieves both the instantaneous rainfall and the rainfall vertical structure** by using a Bayesian approach to match the observed brightness temperatures to hydrometeor profiles derived from cloud resolving models (CRMs).

- **A radiative transfer model** based on a one-dimensional Eddington approximation [Kummerow, 1993] is used to **compute brightness temperatures** from the CRM hydrometeor profiles at the observed satellite frequencies.

- More information on the retrieval algorithm is available from **Kummerow et al. [1996, 2001]**

GPROF Description

- GPROF aims to retrieve the **instantaneous rainfall and the rainfall vertical structure**.

- This is made possible by the response functions for **different channels peaking at different depths within the raining column**.
  - There are, however, more independent variables within raining clouds than there are channels in the observing system.
  - The solution to this problem therefore requires additional assumptions or constraints.

- **Radiative transfer calculations can be used to determine:**
  - brightness temperature vector, **Tb**, given a:
  - vertical distribution of hydrometeors represented by **R**.

GPROF Description

- An inversion procedure, however, is needed to find the hydrometeor profile, **R**, given a vector **Tb**.
  - The present retrieval method has its foundation in Bayes' theorem.

- In Bayes' formulation, the probability of a particular profile **R**, given **Tb** can be written as:

$$\Pr(\mathbf{R} \mid \mathbf{Tb}) = \Pr(\mathbf{R}) \times \Pr(\mathbf{Tb} \mid \mathbf{R})$$

where:

  - $\Pr(\mathbf{R})$ is the probability with which a certain profile
  - **R** will be observed and
  - $\Pr(\mathbf{Tb} \mid \mathbf{R})$ is the probability of observing the brightness temperature vector, **Tb**, given a particular rain profile **R**.

- The first term on the right-hand side the equation is derived using cloud-resolving models (CRM).

GPROF 2010

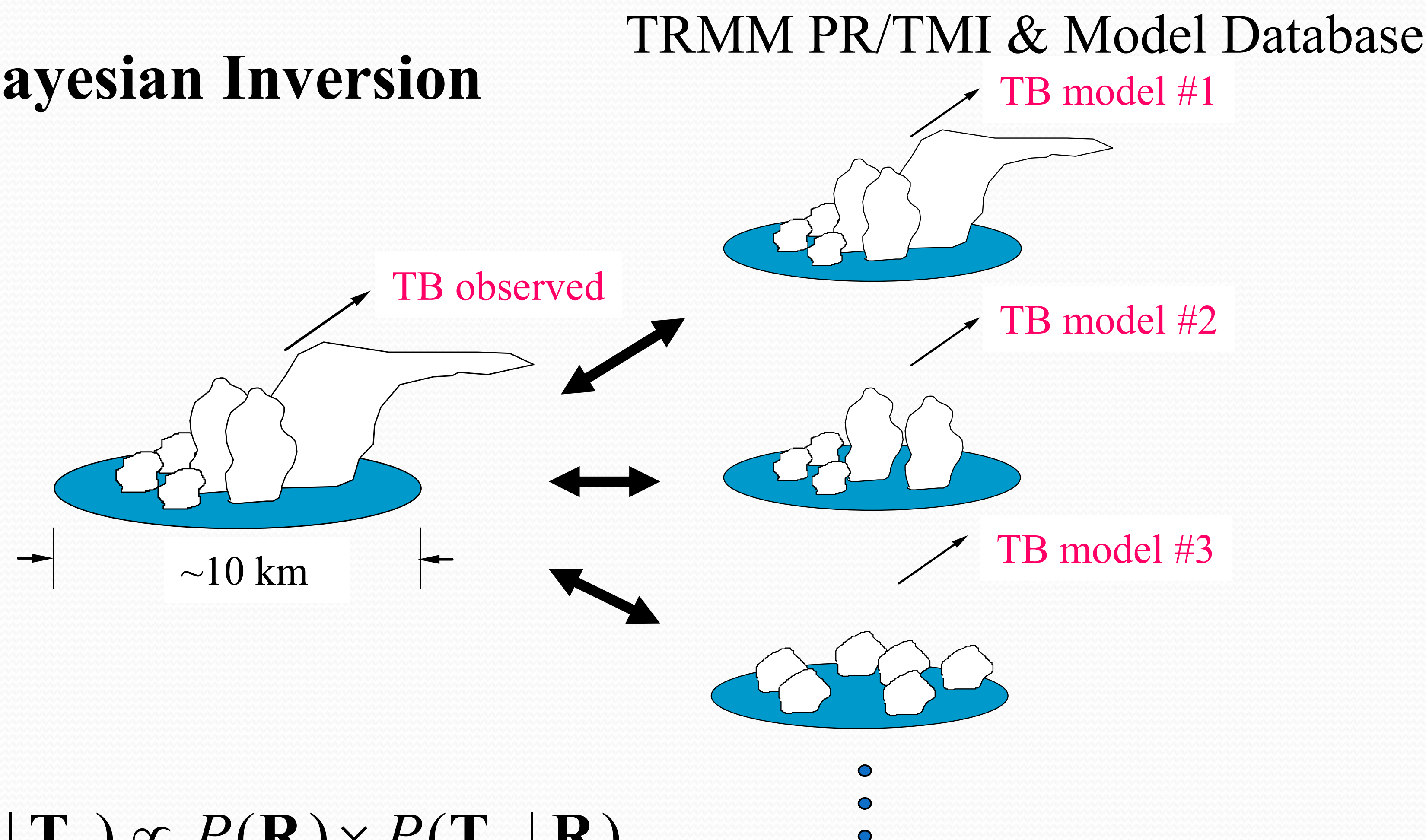
- GPROF 2010 continues to be a Bayesian algorithm consisting of:

$$P(R|Tb) = P(Tb|R) \cdot P(R)/P(Tb)$$

- No more rain screens. All pixels are compared to database. Bayes' theorem determines rain or no rain. Consequence: almost all pixels have a very small probability of rain.
- No more convective/stratiform separation. Only necessary because CRM database was skewed to convective pixels. Entire code is now exceedingly simple.
- Pixels are classified only by background SST and Total Precipitable Water (TPW). Database entries within ± 1K in SST and ± 2 mm in TPW are searched for potential solutions. Error covariances are established from fit between observed and simulated Tb in the a-priori database.

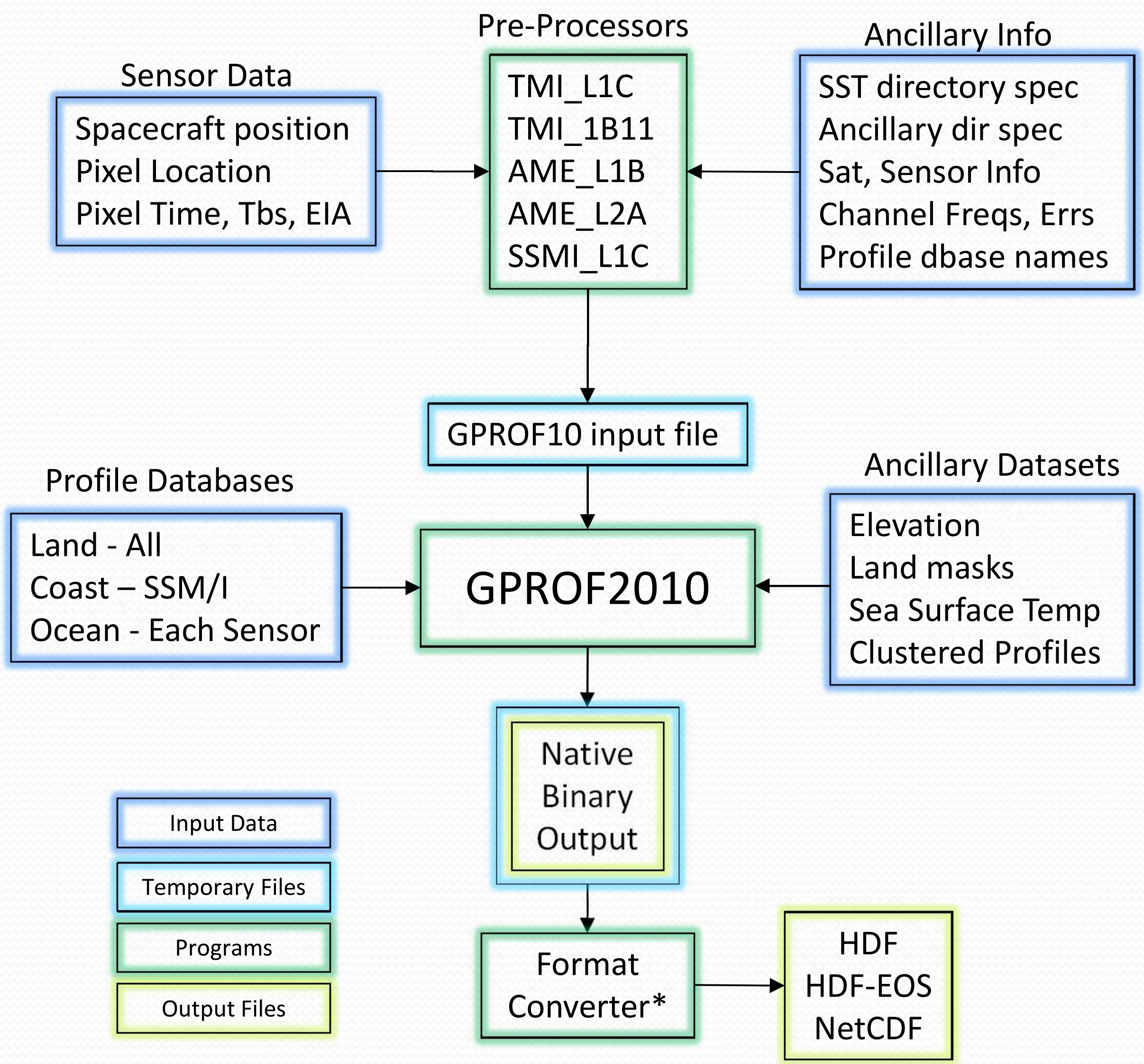
GPROF Algorithm Description

Bayesian Inversion

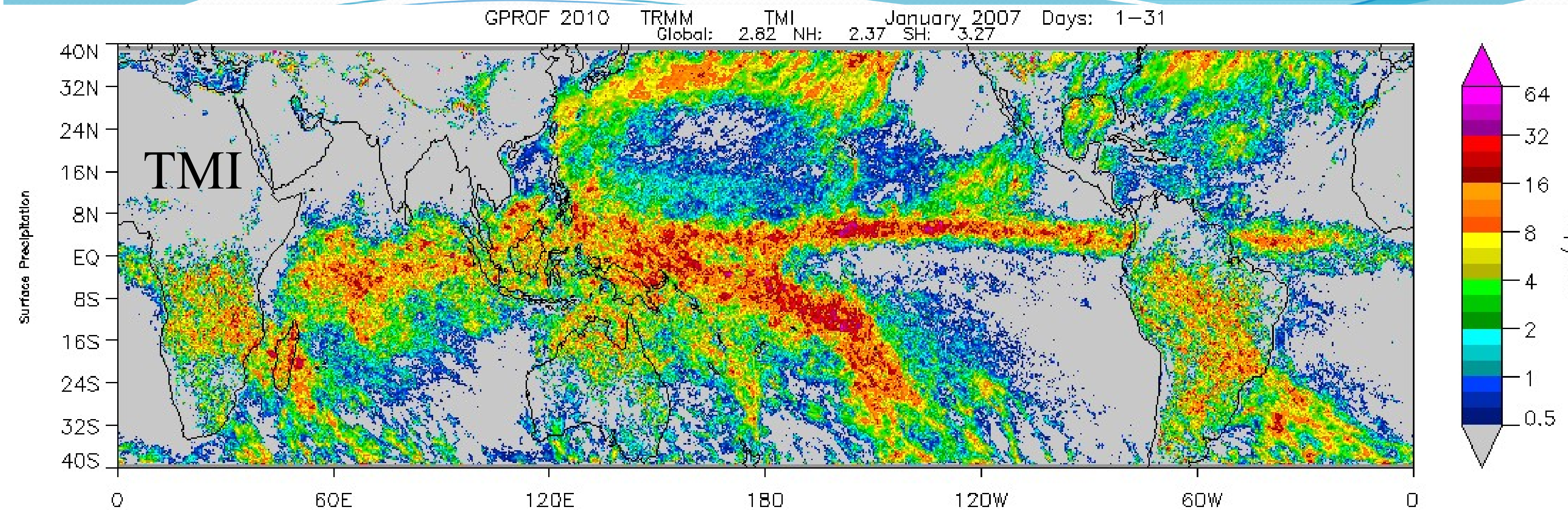


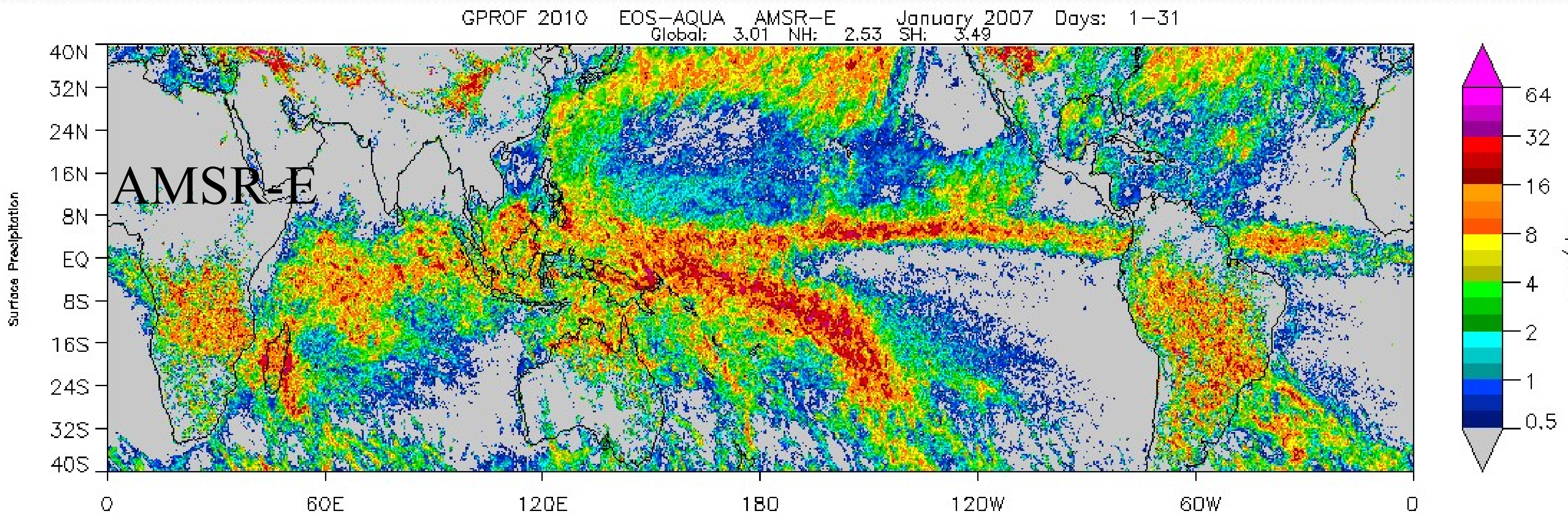
$$P(\mathbf{R}\,|\,\mathbf{T_b}) \propto P(\mathbf{R}) \times P(\mathbf{T_b}\,|\,\mathbf{R})$$

GPROF 2010 Processing Algorithm

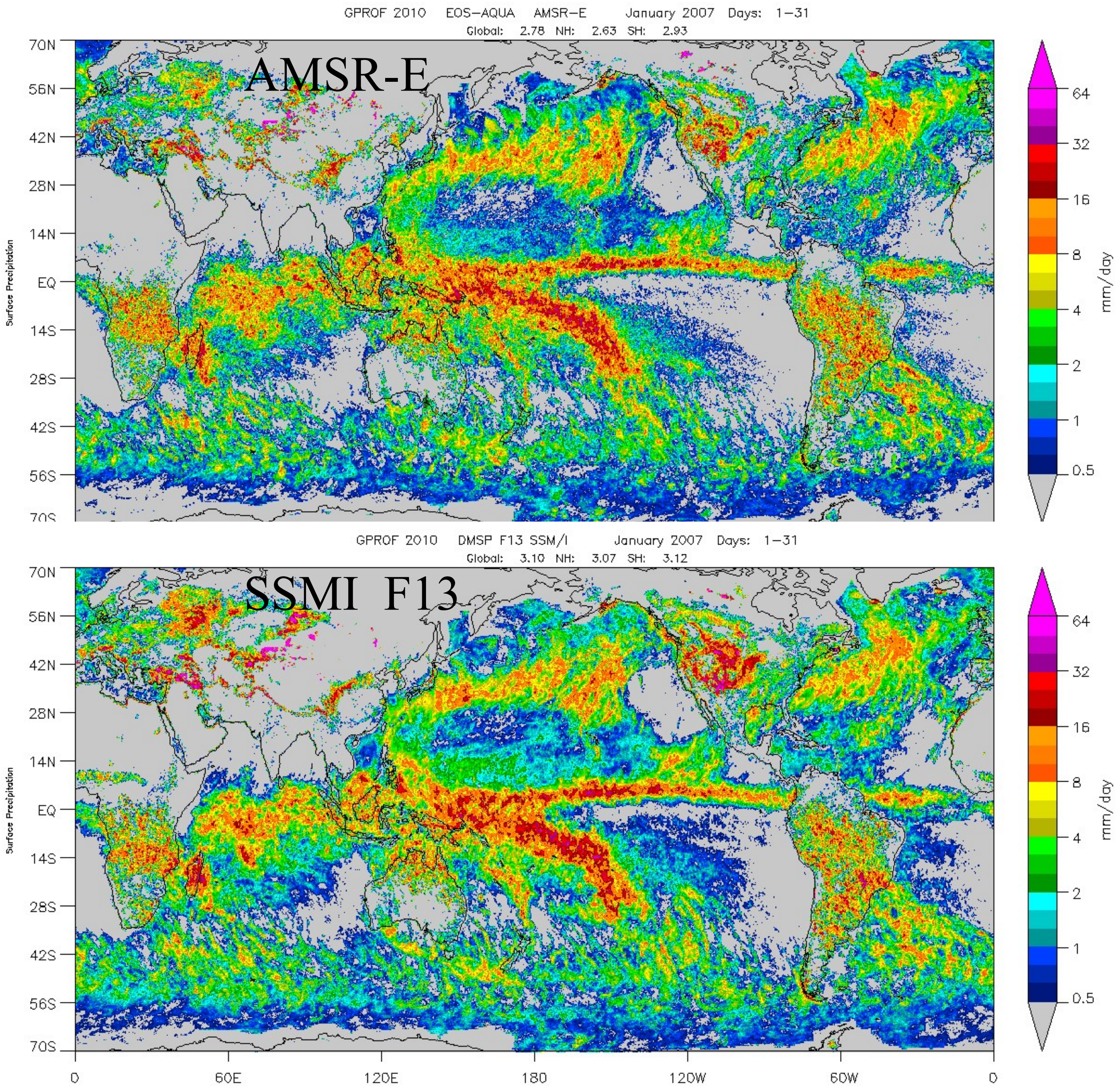


Jan 2007


GPROF 2010 TRMM TMI January 2007 Days: 1-31
Global: 2.82 NH: 2.37 SH: 3.27
TMI
Surface Precipitation
40N
32N
24N
16N
8N
EQ
8S
16S
24S
32S
40S
0
60E
120E
180
120W
60W
0
64
32
16
8
4
2
1
0.5
mm/day


GPROF 2010 EOS-AQUA AMSR-E January 2007 Days: 1-31
Global: 3.01 NH: 2.53 SH: 3.49
AMSR-E
Surface Precipitation
40N
32N
24N
16N
8N
EQ
8S
16S
24S
32S
40S
0
60E
120E
180
120W
60W
0
64
32
16
8
4
2
1
0.5
mm/day

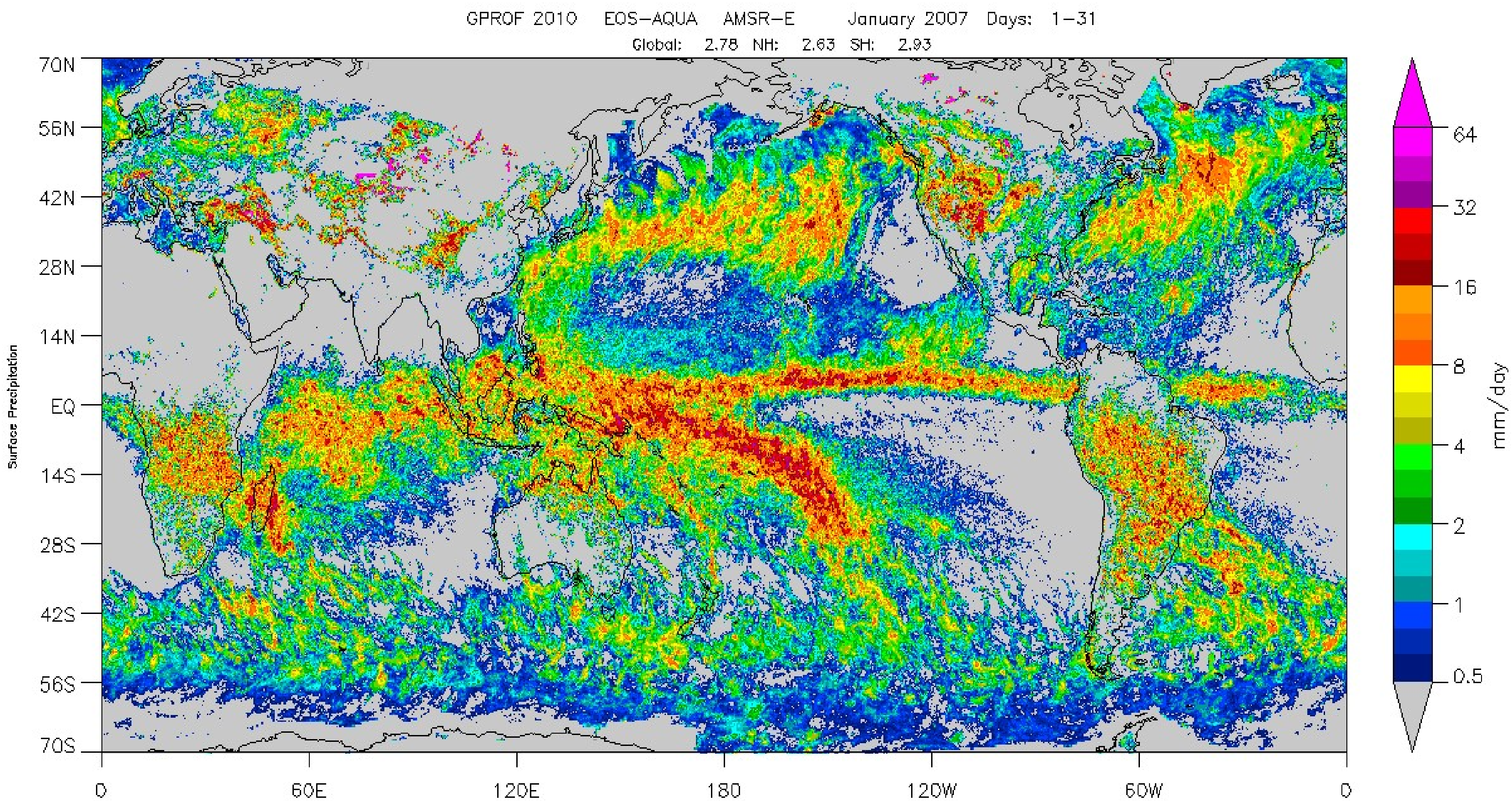
Jan 2007



GPROF 2010 EOS-AQUA AMSR-E January 2007 Days: 1-31
Global: 2.78 NH: 2.63 SH: 2.93
AMSR-E
Surface Precipitation
mm/day
GPROF 2010 DMSP F13 SSM/I January 2007 Days: 1-31
Global: 3.10 NH: 3.07 SH: 3.12
SSMI F13
Surface Precipitation
mm/day

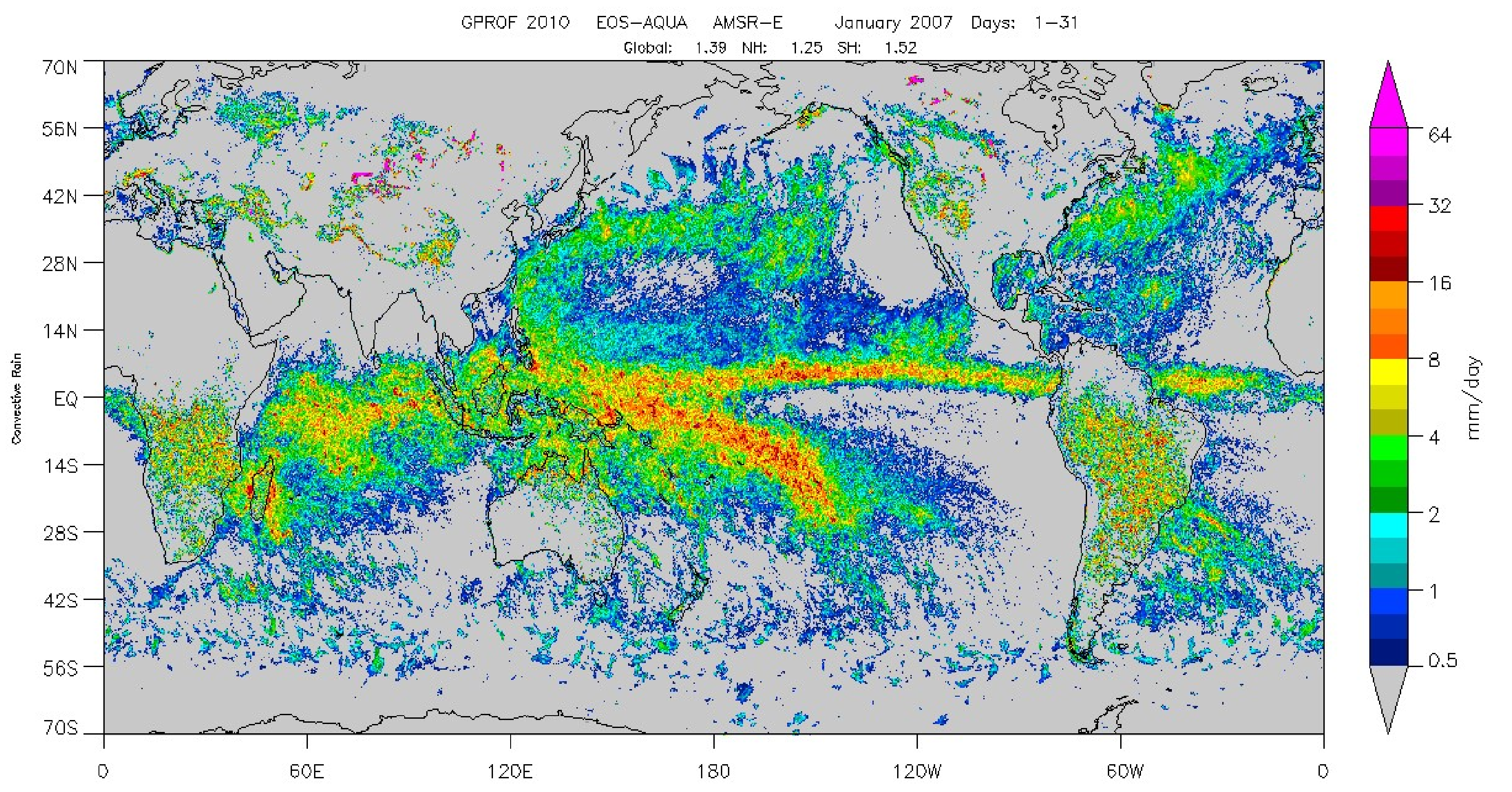
Jan 2007

GPROF 2010 Surface Precipitation (Liquid+Frozen)



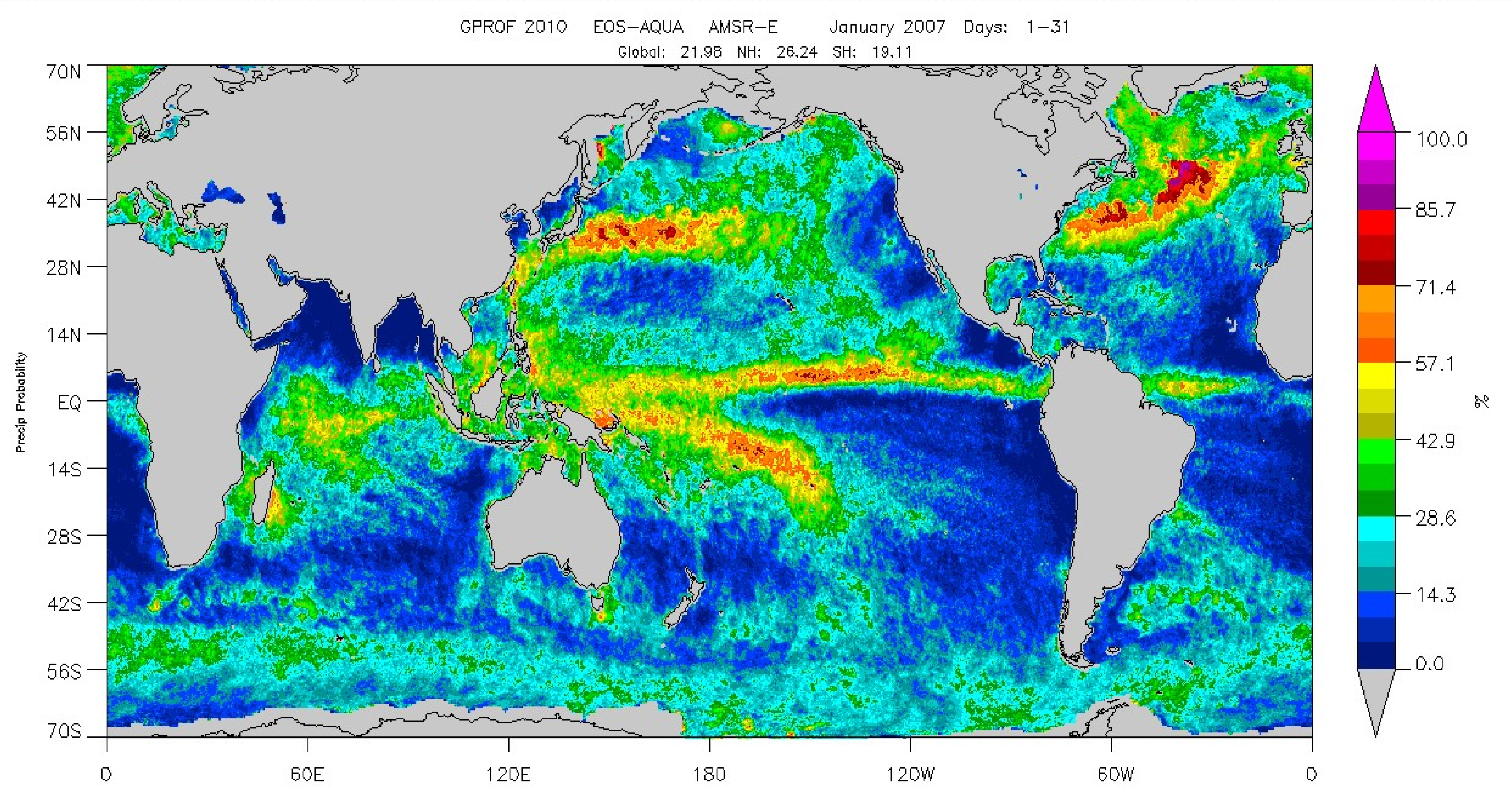
Jan 2007

GPROF 2010 Convective Rain



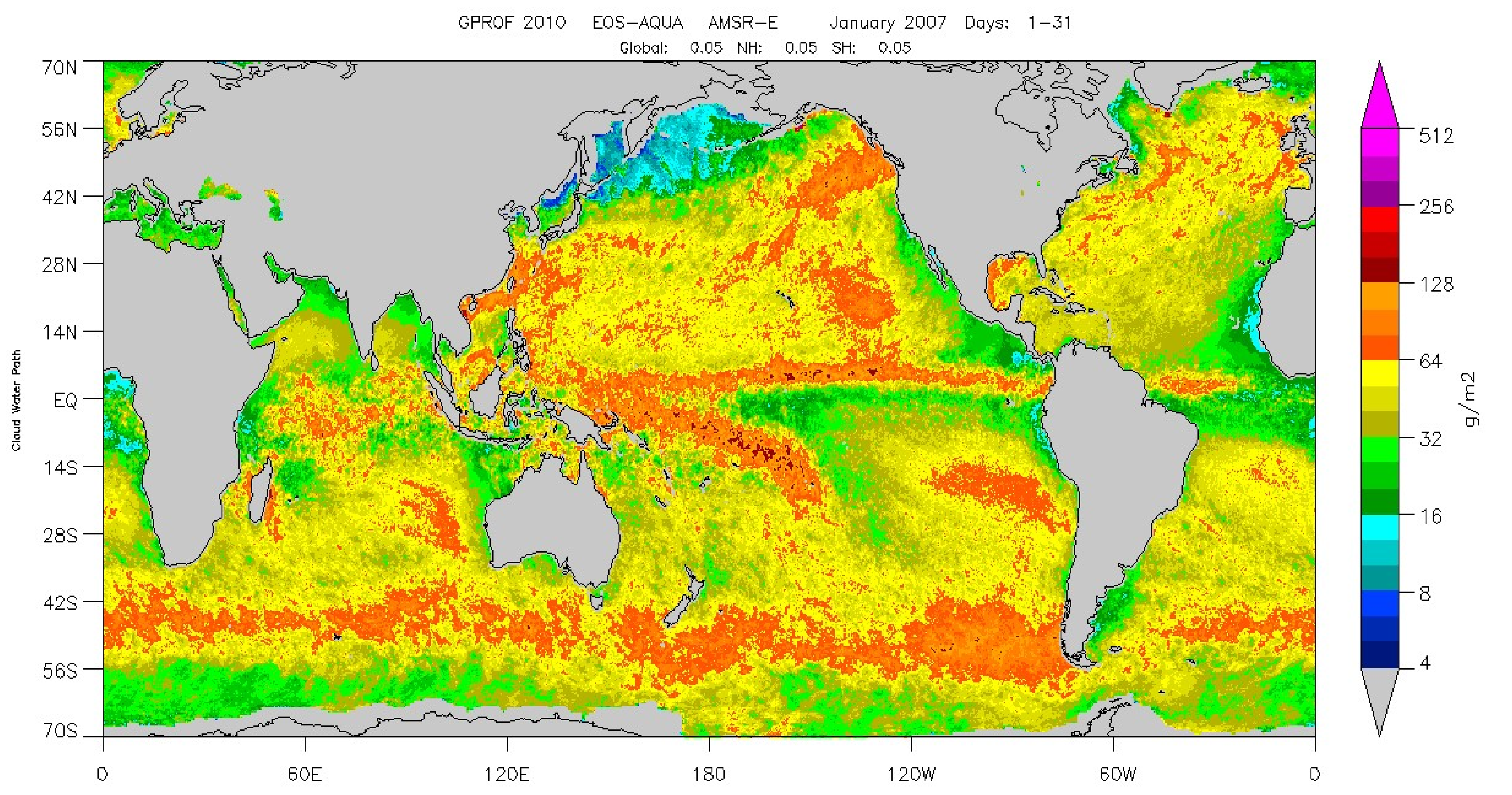
Jan 2007

GPROF 2010 Probability of Precipitation



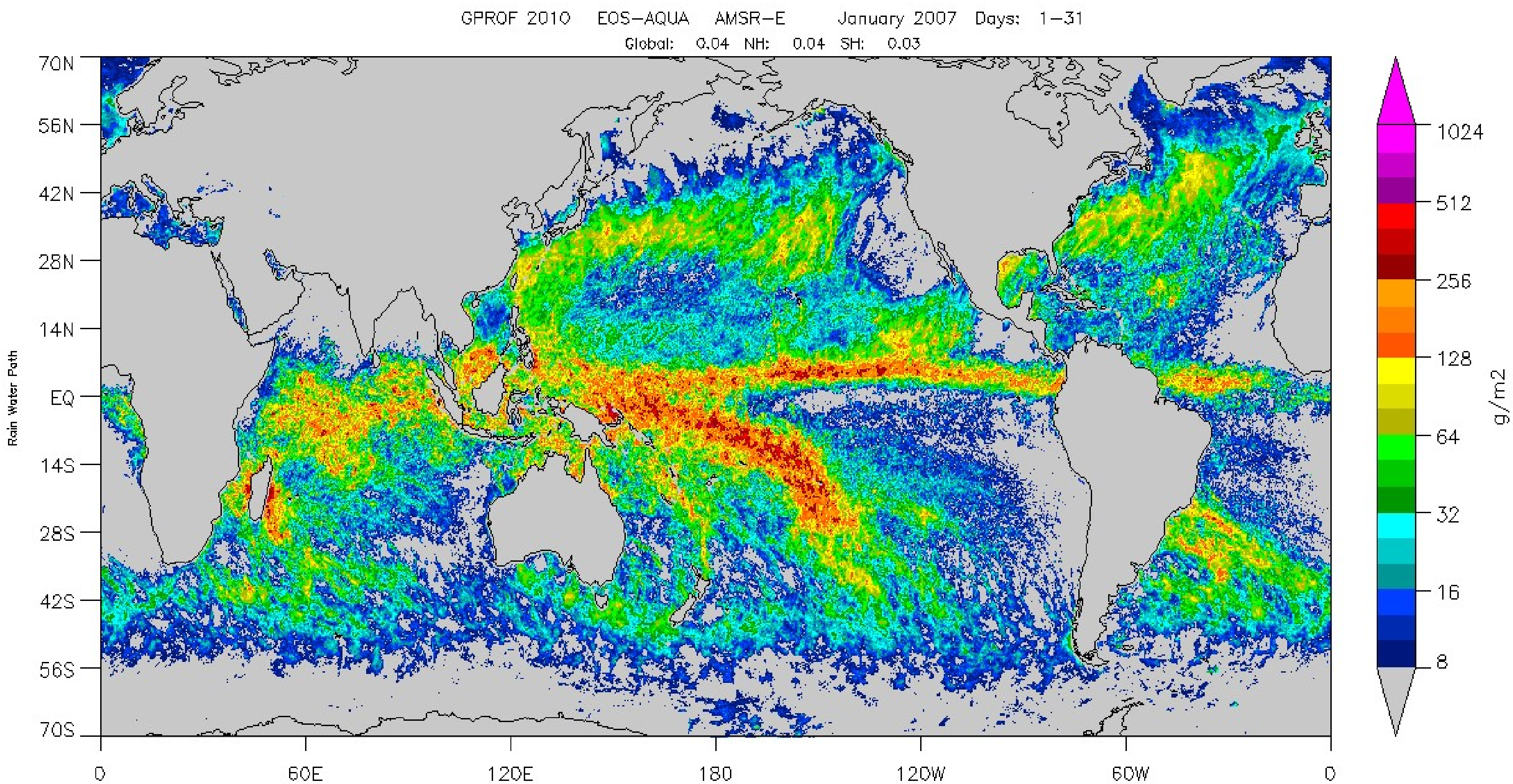
Jan 2007

GPROF 2010 Cloud Water Path



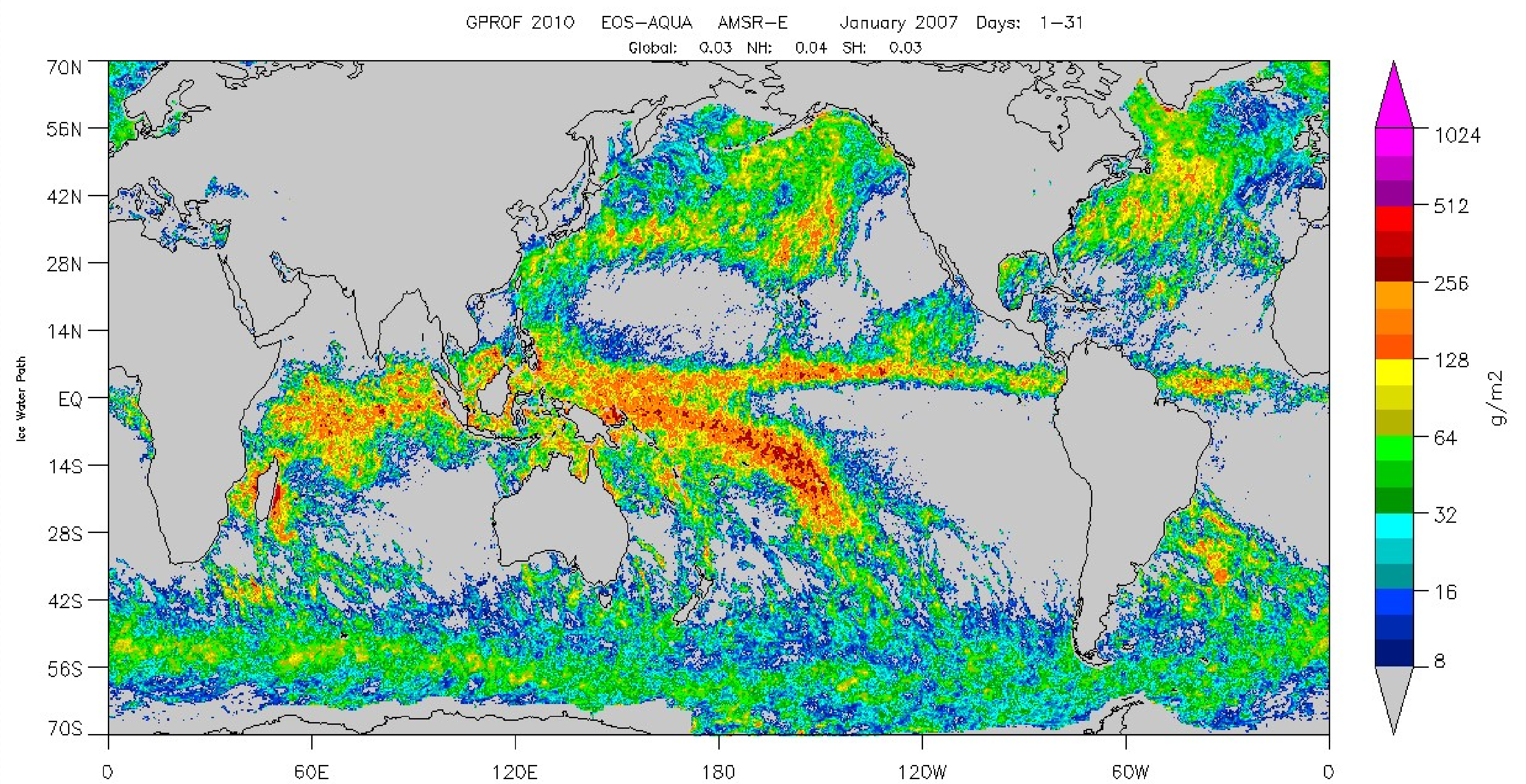
Jan 2007

GPROF 2010 Rain Water Path



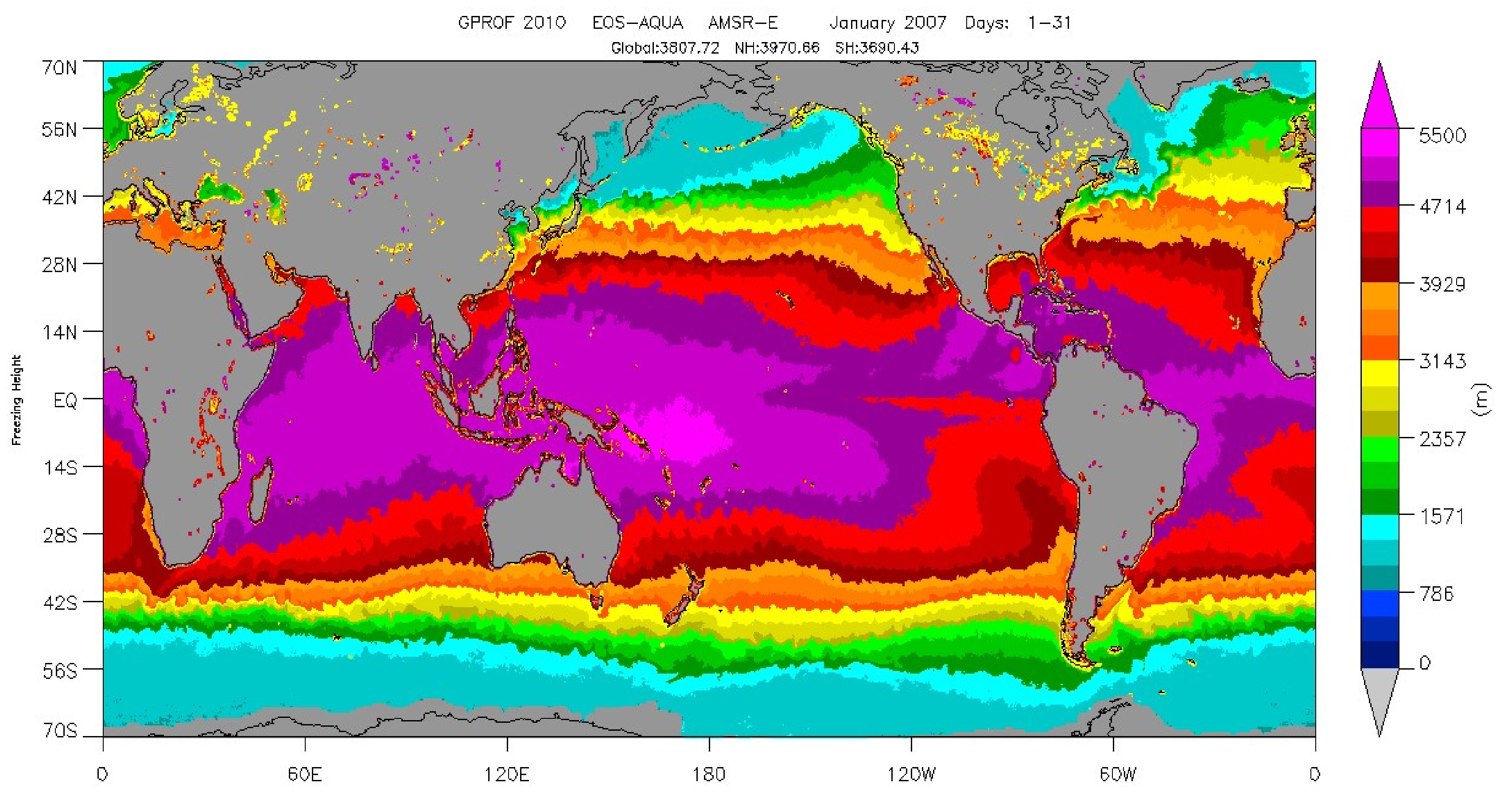
Jan 2007

GPROF 2010 Ice Water Path



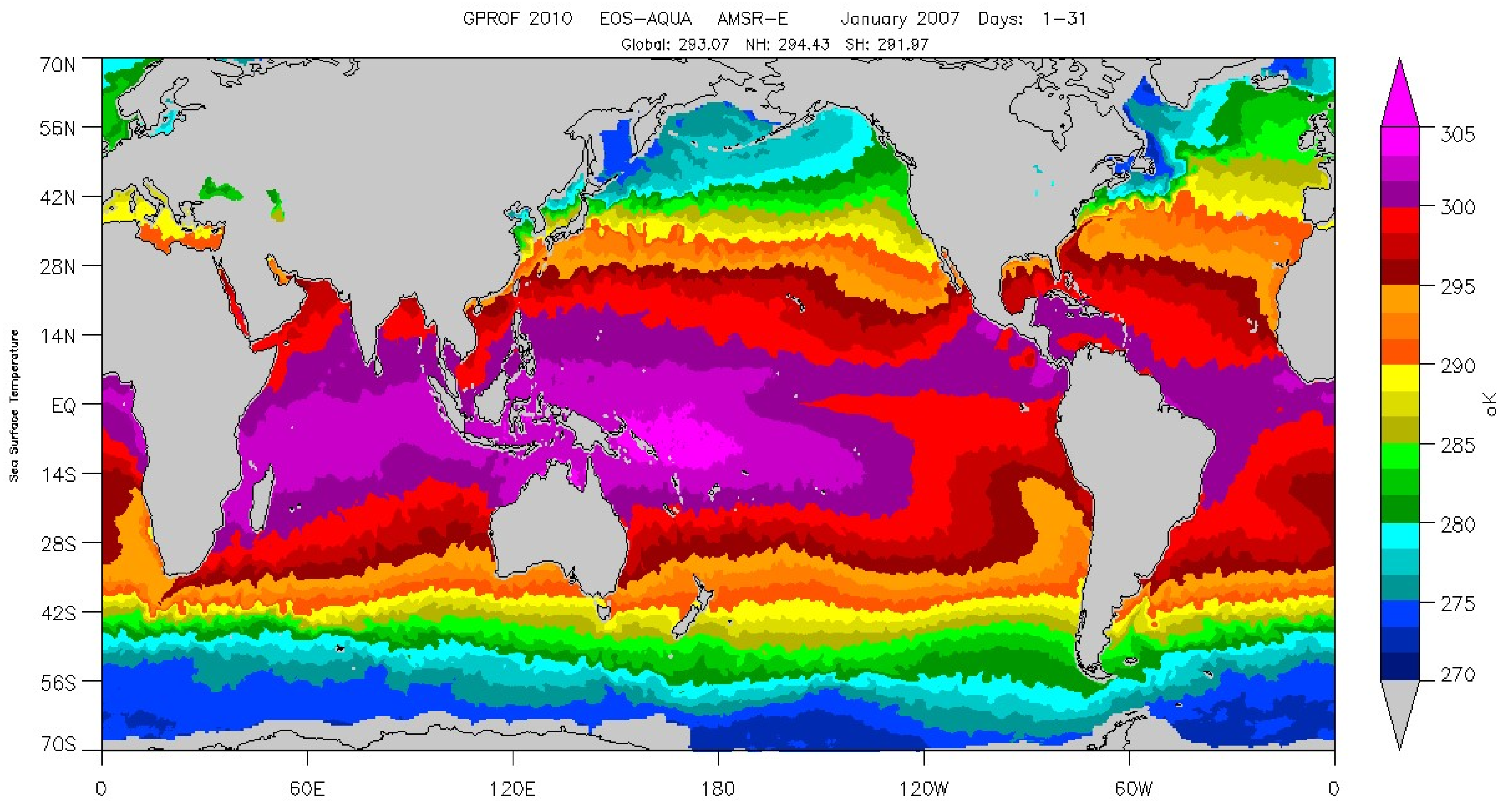
Jan 2007

GPROF 2010 Freezing Height



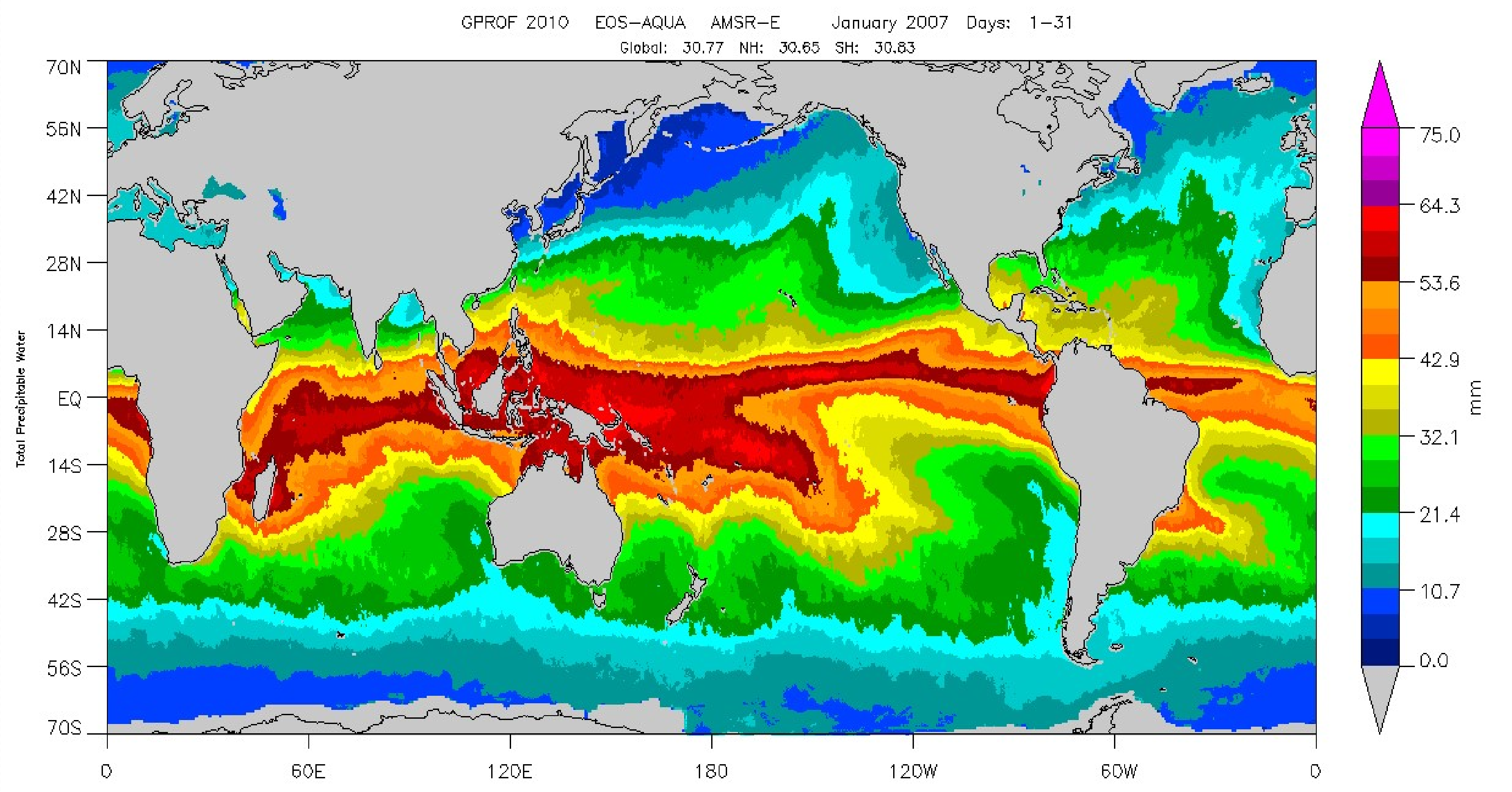
Jan 2007

GPROF 2010 Sea Surface Temperature



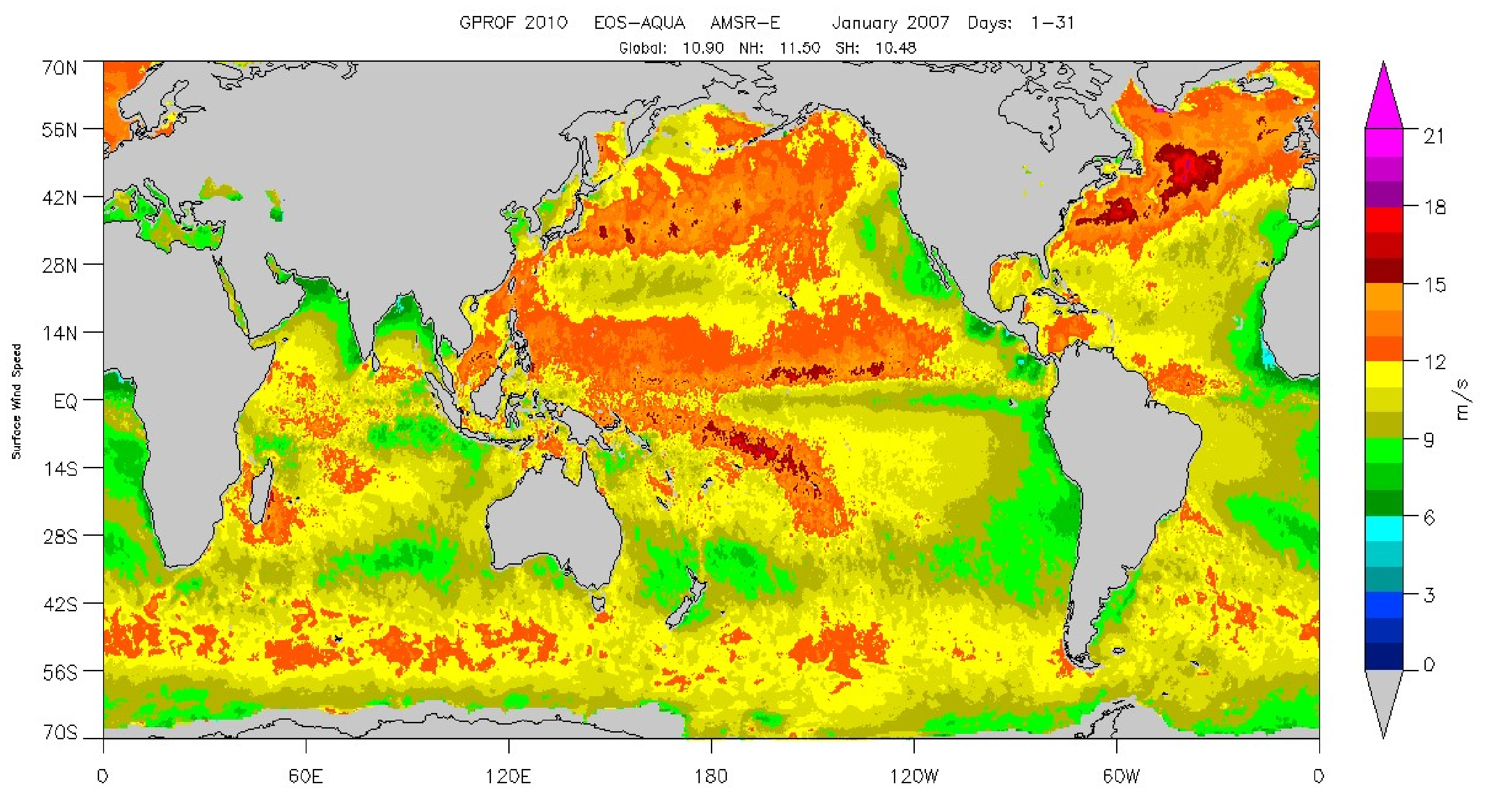
Jan 2007

GPROF 2010 Total Precipitable Water



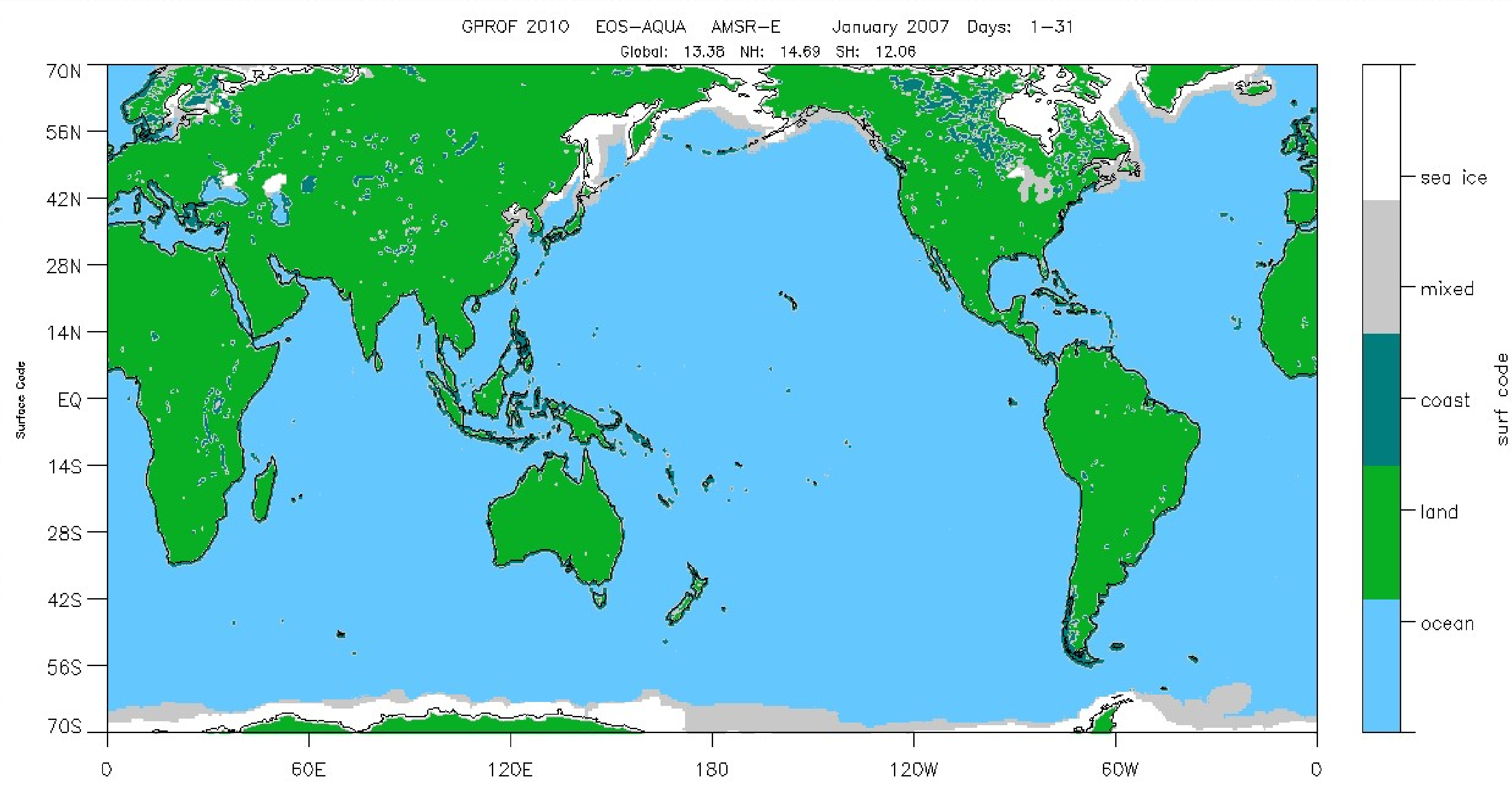
Jan 2007

GPROF 2010 Wind Speed



Jan 2007

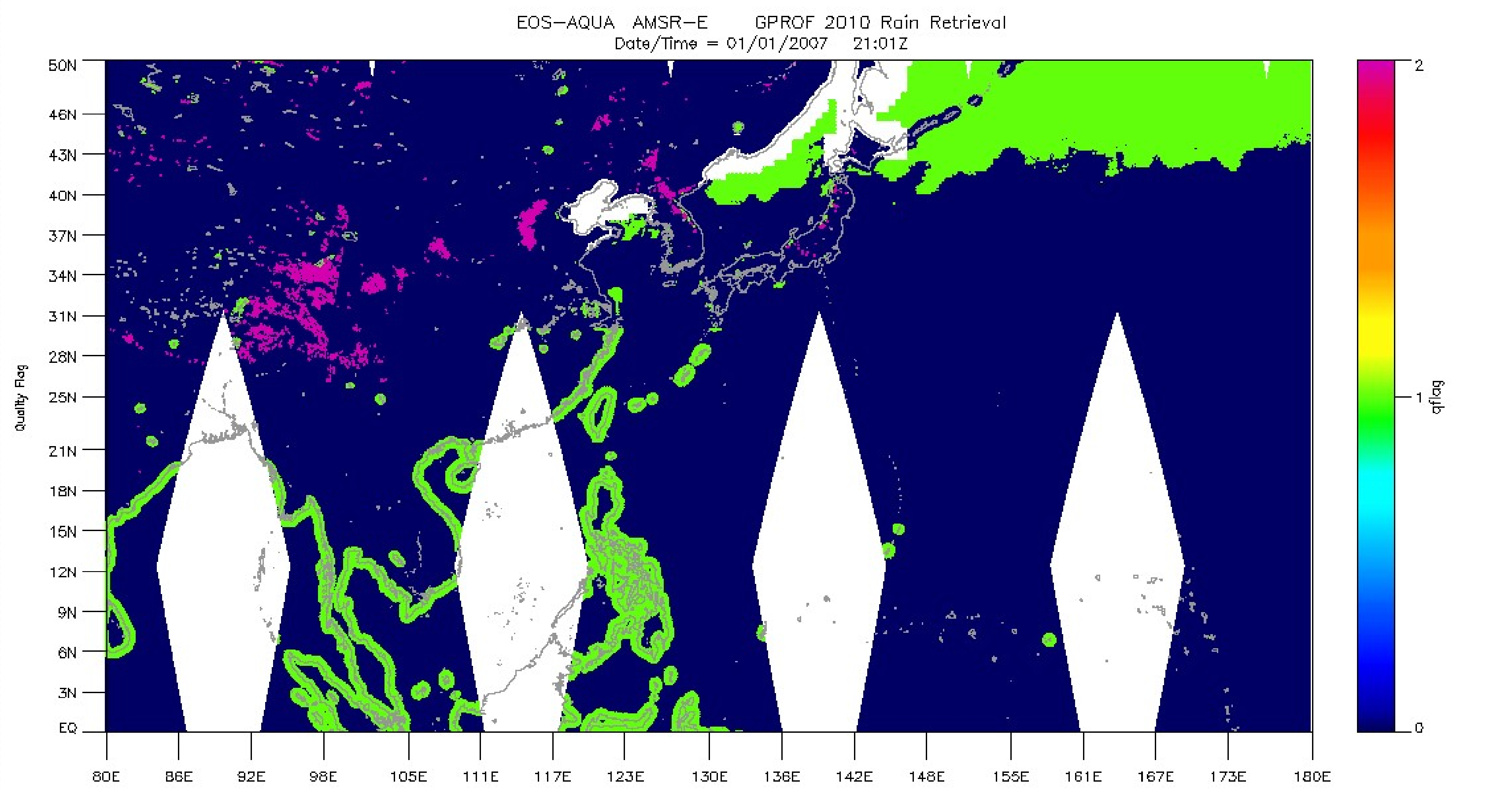
GPROF 2010 Surface Type



Jan 1st, 2007

GPROF 2010 Quality Flag

0 = Best Quality
1 = Sun-glint, Bayesian Expansion, Coastal contamination, database expanding
2 = Ambiguous over Land



GPCP V3 Products and Inputs

Product scale and coverage	***Input data***
	6 a.m./p.m. GPROF-SSMI/SSMIS August 1987–present
	Monthly Susskind TOVS/AIRS August 1987–present
	GridSat-B1 1982–2010 (to be extended)
Monthly 1979–present	CPC 4-km Merged IR 2011–present
0.5° global	OPI 1979–present
	GPCC Full Gauge Analysis 1979–2010 (to be extended)
	GPCC Monitoring Gauge Analysis 2011–present
	TRMM Composite Climatology
	nnHIRS reanalysis data (T, RH, sfc p)
Pentad 1979–present	CMAP Pentad Precipitation 1979–present
0.5° global	GPCP Daily 1982–present
	GPCP Monthly 1982–present
Daily 1982–present	6 a.m./p.m. GPROF-SSMI/SSMIS August 1987–present
0.5° 60° N-S 1982–1996	Daily Susskind TOVS/AIRS October 1996–present
0.5° global 1996–present	Gridsat-B1 1982-2010 (to be extended)
	CPC 4-km Merged IR 2011–present
	GPCP 3-hr 1998–present
3-hr 1998–present	GPCP Monthly 1998–present
0.1° 60° N-S (to be extended)	GPM IMERG 1998–present

GPCP V3 Output Data Fields

- **The standard monthly precipitation estimate will be a satellite-gauge combination**
- **The shorter-interval products will be calibrated to the monthly satellite-gauge product**
- **Data fields in al products:**
  - Accumulated precipitation (mm/d)
  - Estimated error
  - Precipitation phase (percentage probability of liquid)
- **The Monthly dataset will also provide:**
  - Multi-satellite accumulated precipitation (e.g., without month-to-month gauge information; mm/d)
  - gauge relative weighting in the final satellite-gauge product
- **The 3-hourly dataset will also provide**
  - snapshot precipitation rate (expressed in mm/d)

GPCP V3 Observation-Model Products

- **Numerical models are more skillful than observational products for cold-season mid- and high-latitude precipitation**
  - This is a moving target as both sides improve!
- **In parallel with (not replacement of) the observational products, this project plans to create monthly observation-model products:**
  - start work using the NASA Modern-Era Retrospective Analysis for Research and Application (MERRA)
  - blend the GPCP multi-satellite and MERRA precipitation fields following Sapiano et al (2008)
  - The combine the gauges with the blended satellite-model field
- **Shorter-interval combinations currently lack a good framework**
  - Note the recent word by Xie and collaborators on merging daily satellite, gauge, and radar data

Prototype Monthly V3 vs. V2.2

0.5° resolution

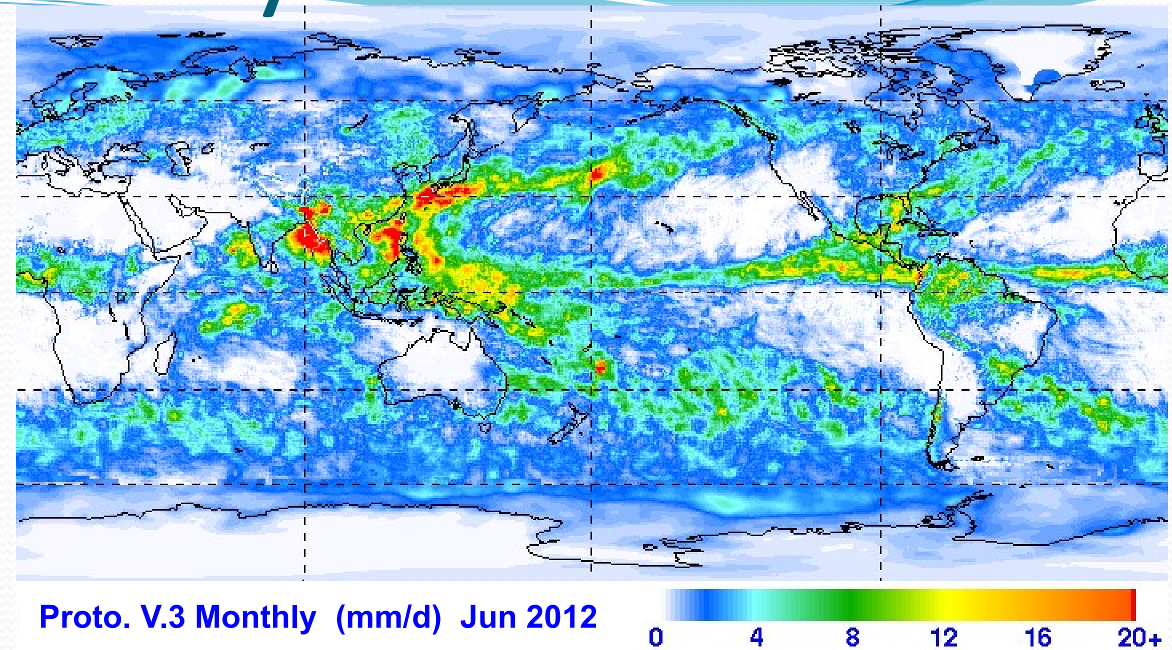
Microwave-adjusted IR extends 60° N-S

TOVS/AIRS dominates 60-90° N and S

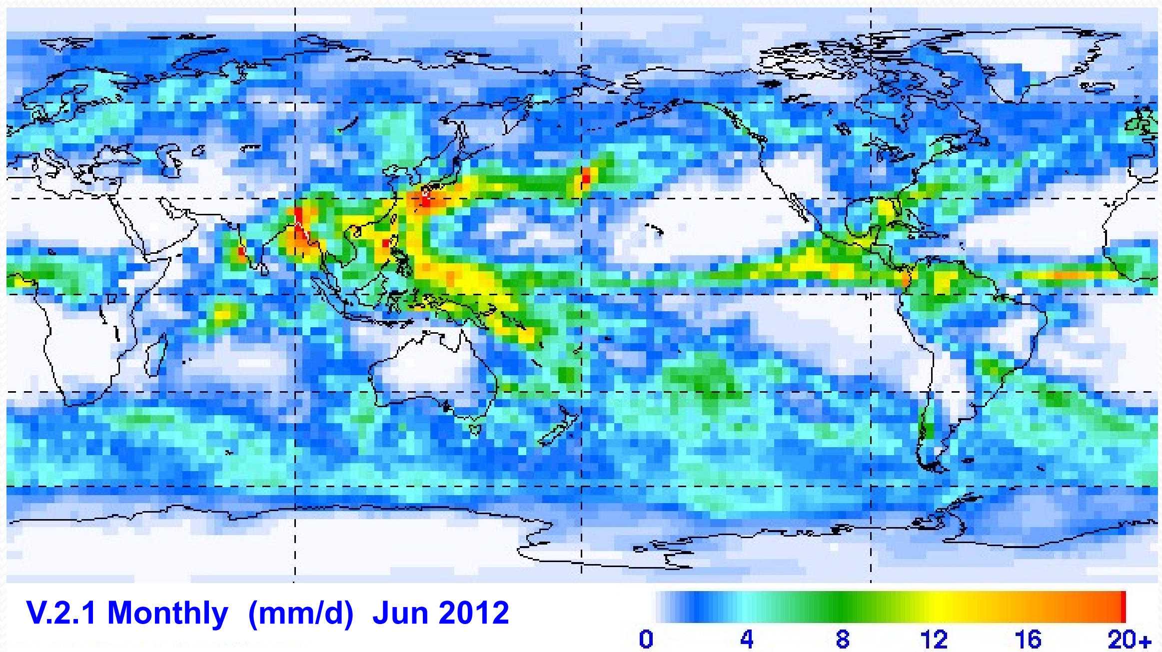
microwave-only 40-60° N and S

Microwave-adjusted IR extends 40° N-S

2.5° resolution



Proto. V.3 Monthly (mm/d) Jun 2012



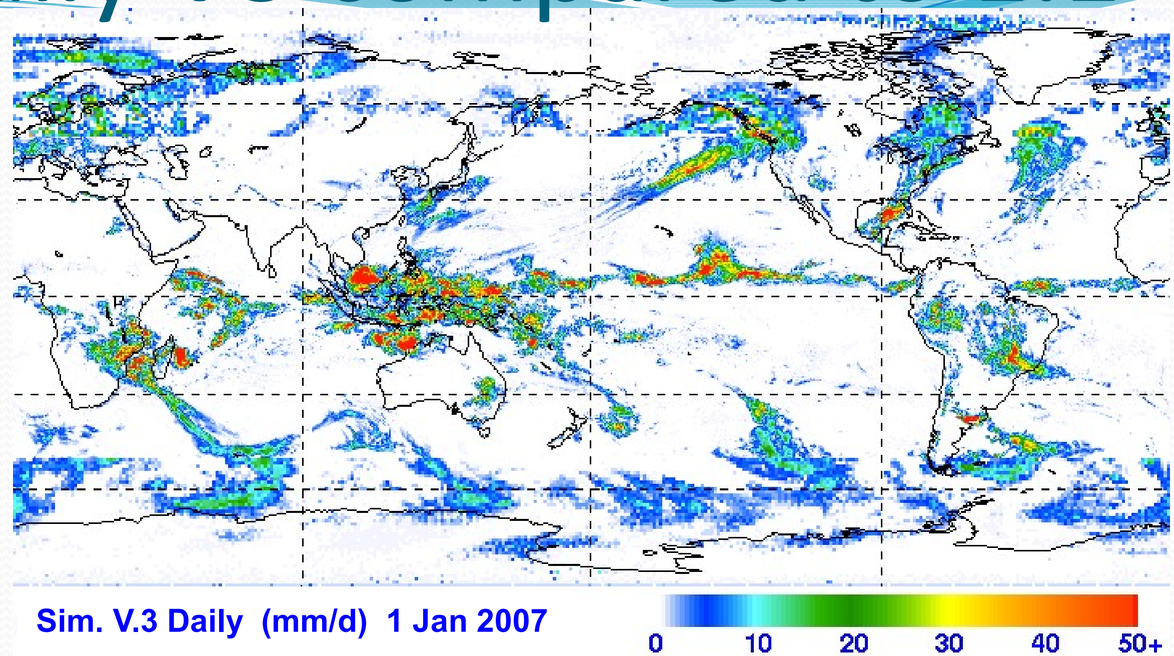
V.2.1 Monthly (mm/d) Jun 2012

Simulated Daily V3 compared to 1.1

0.5° resolution

Microwave-adjusted IR extends 60° N-S

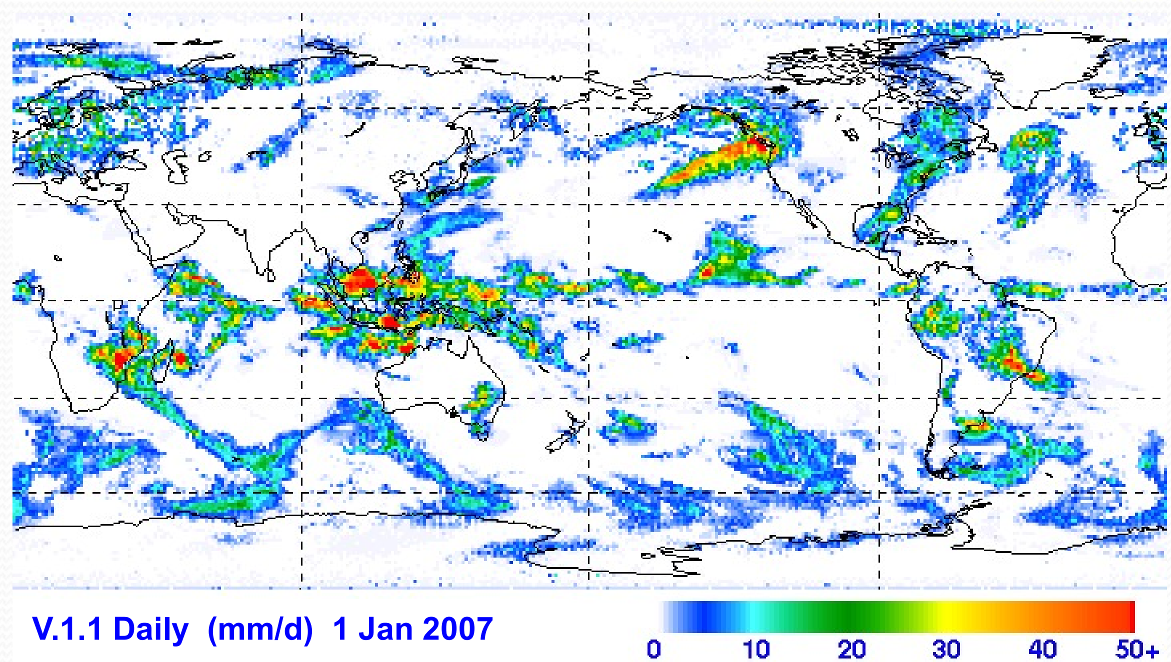
TOVS/AIRS used 60-90° N and S



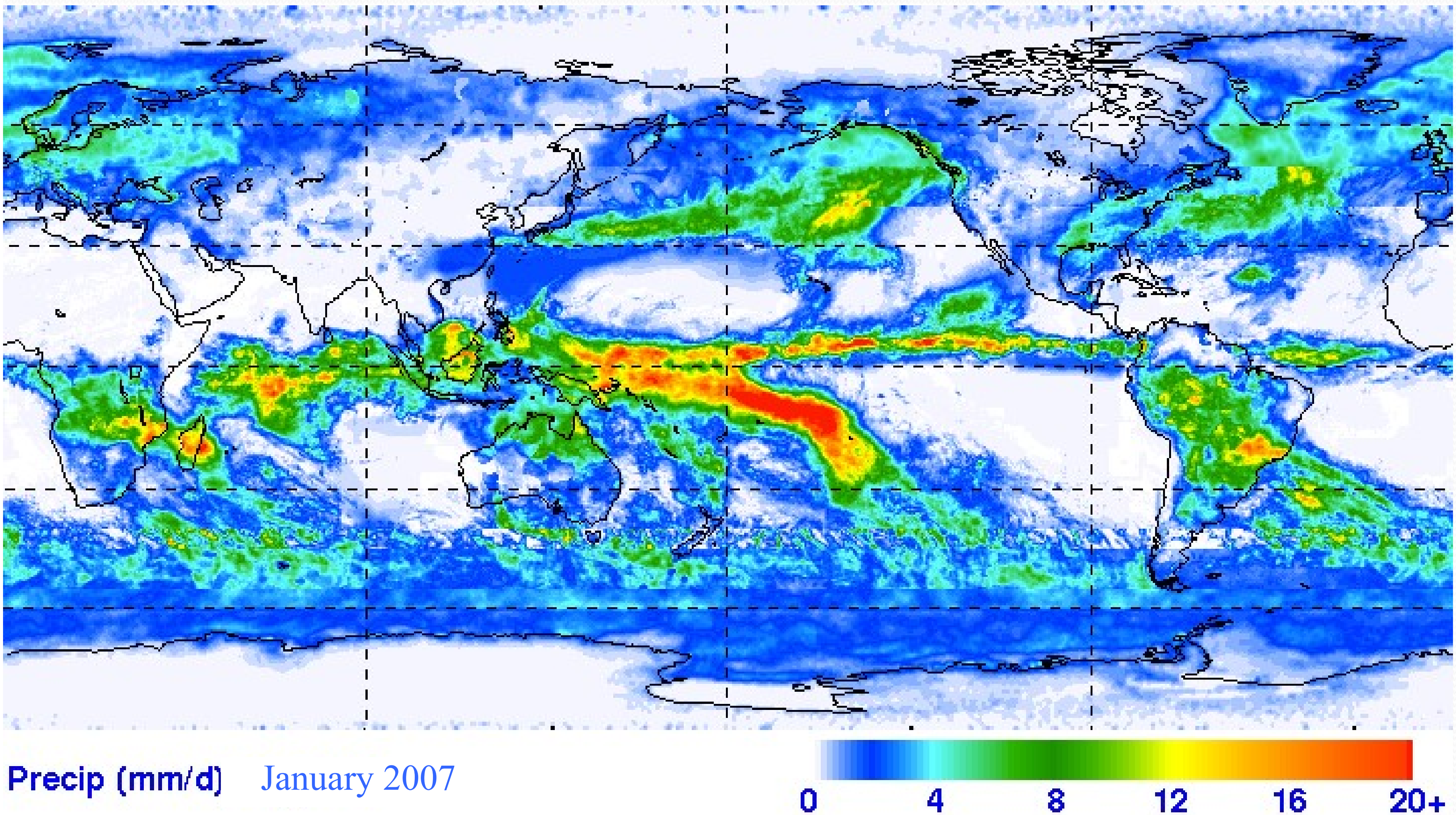
TOVS/AIRS used 40-90° N and S

Microwave-adjusted IR extends 40° N-S

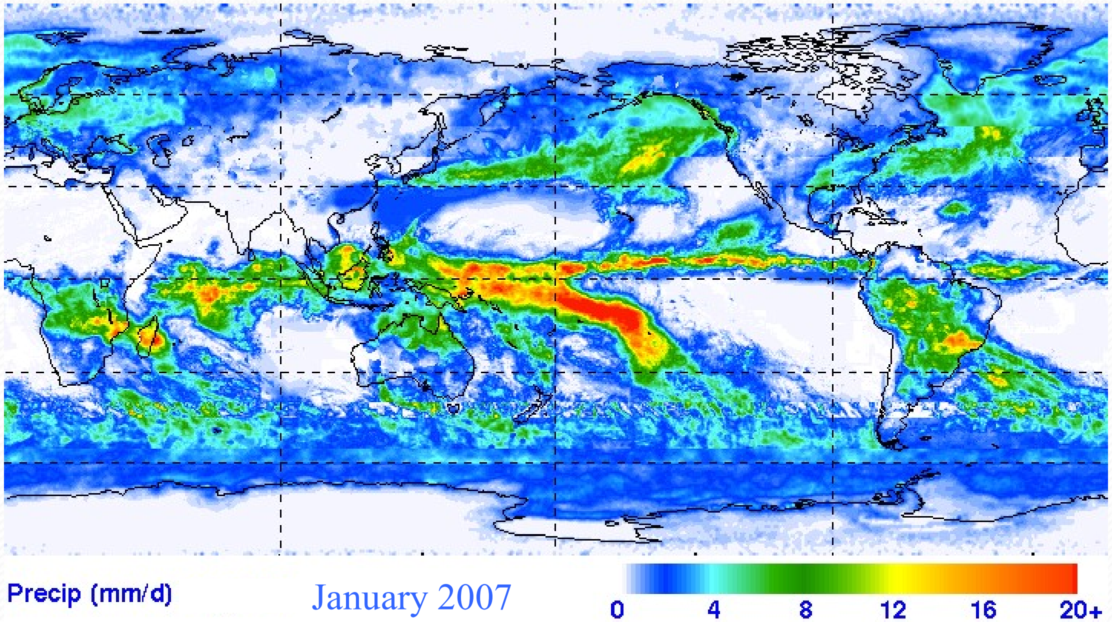
1° resolution



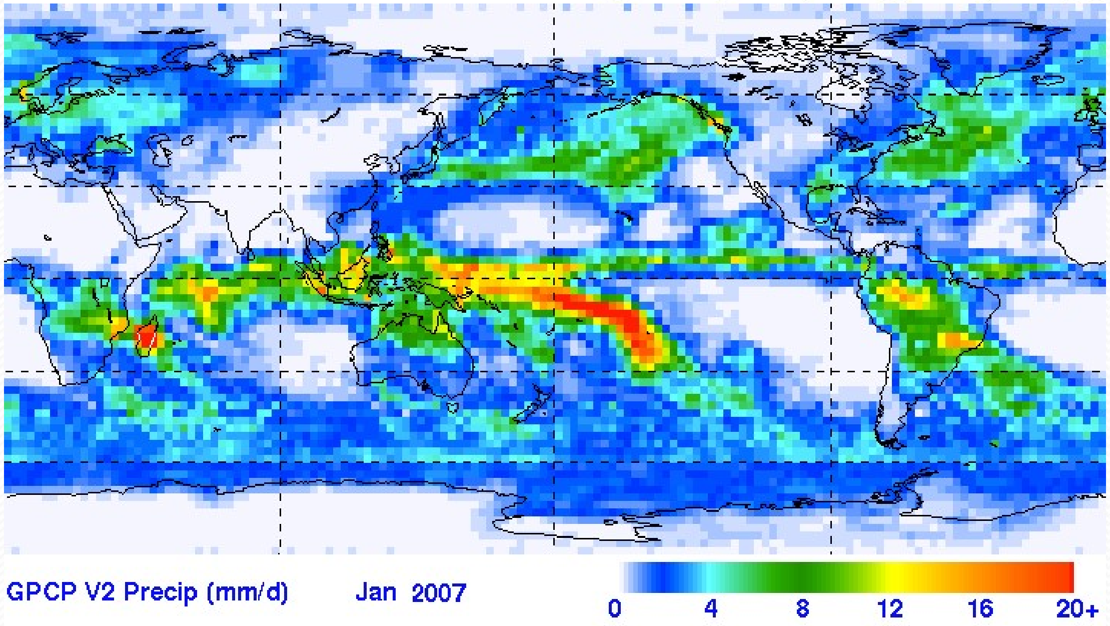
Example GPCP Version 3 Monthly



Example Monthly V3 s. V2.1

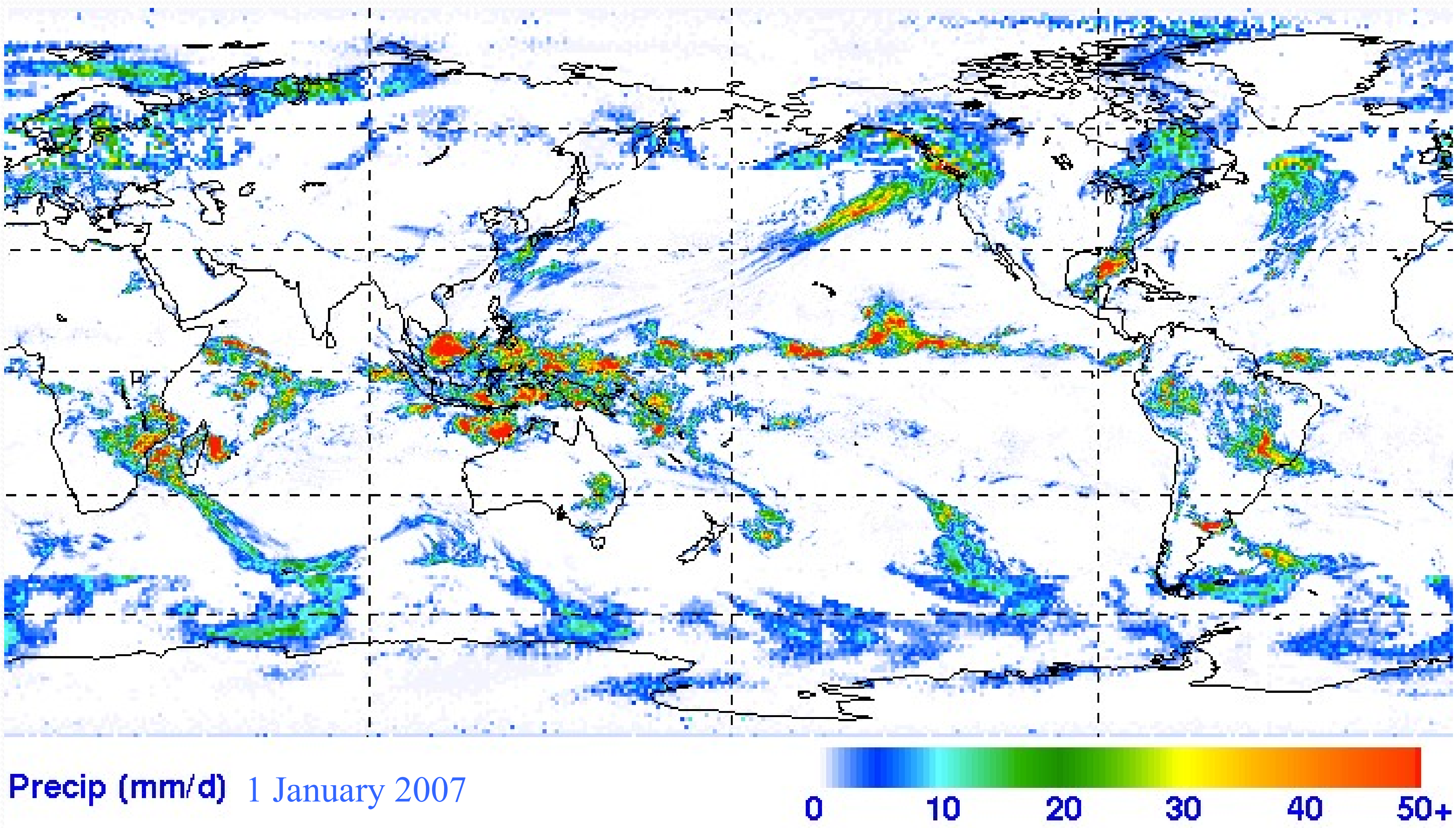


Version 3

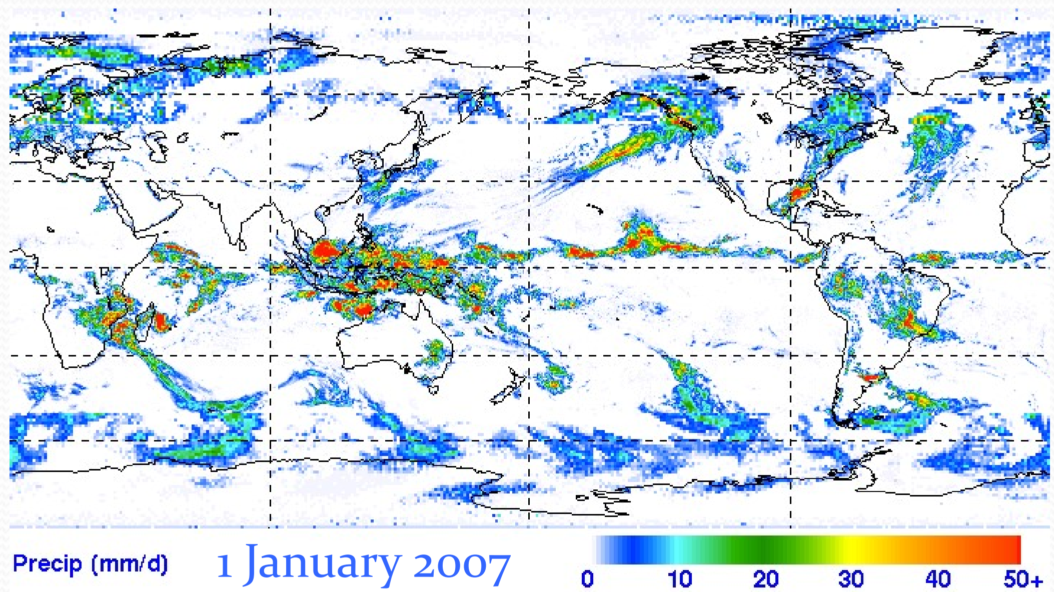


Version 2.1

Example GPCP Version 3 Daily

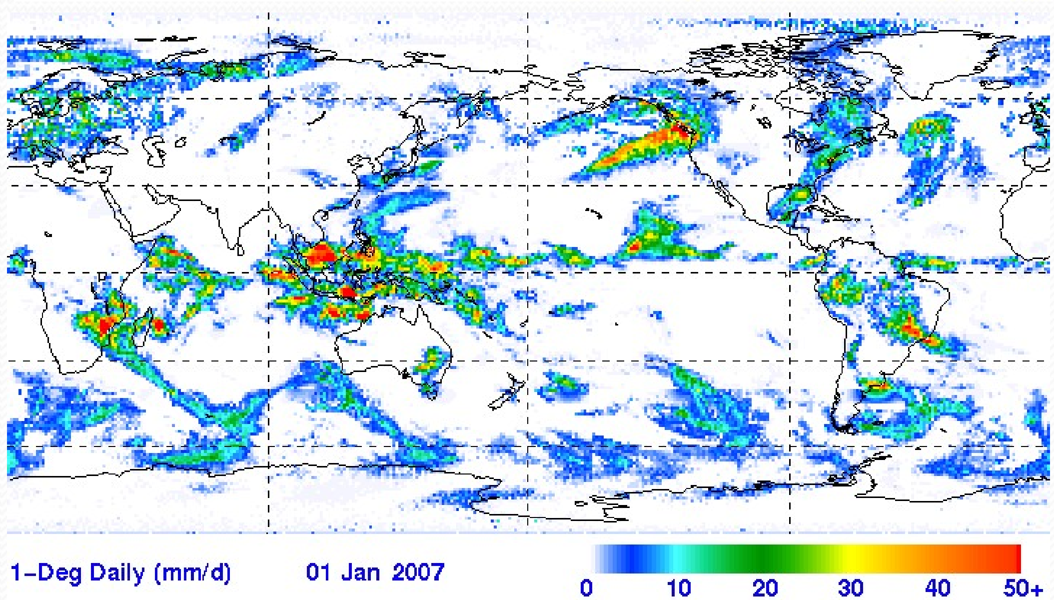


Daily Example GPCP V3 vs. V2.1



NEW Version 3

- Mostly microwave
- 50° N-50° S
- [1998-present]
- 0.5° resolution

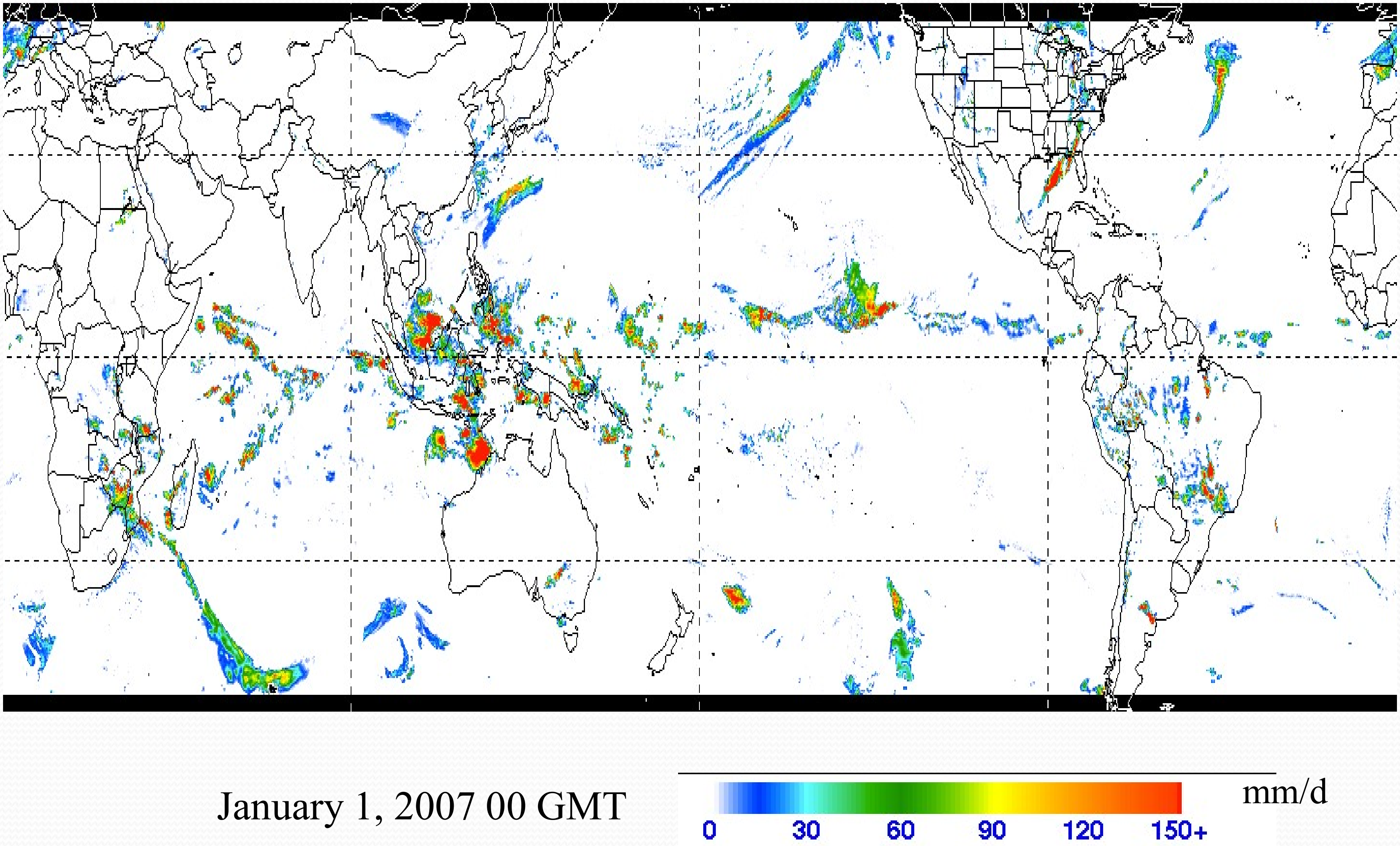


Version 2.1

- IR adjusted by microwave 40° N-40° S
- 1.0° resolution

Polar regions (>60°) the same in both versions

Example GPCP Version 3 3-hr Product (50N-50S)



Summary

- **GPCP products are intensely used by the community**
  - they received many questions/complaints when they fell behind due to SSMIS issue (inconsistency of data)
  - Be patient for release of new products, it's worth the wait.

- **NOAA is supporting transfer of GPCP Version 2 (V2.3)** set of products for operational processing at NOAA/NCDC

- **Version 3 development way behind** GRP schedule due to delays in input data sets and V2 problems

Standard references for the combined precipitation data sets include the following:

- **Satellite-Gauge:**
  - 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, P. Arkin, 2003: The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present). *J. Hydrometeor*., 4,1147-1167.
- **Pentad:**
  - Xie, P., J.E. Janowiak, P.A. Arkin, R.F. Adler, A. Gruber, R.R. Ferraro, G.J. Huffman, S. Curtis, 2003: GPCP Pentad Precipitation Analyses: An Experimental Dataset Based on Gauge Observations and Satellite Estimates. *J. of Climate*, 16, 2197-2214.
- **1DD:**
  - 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, 36-50.