Science Issues With Controlled Re-Entry Of TRMM

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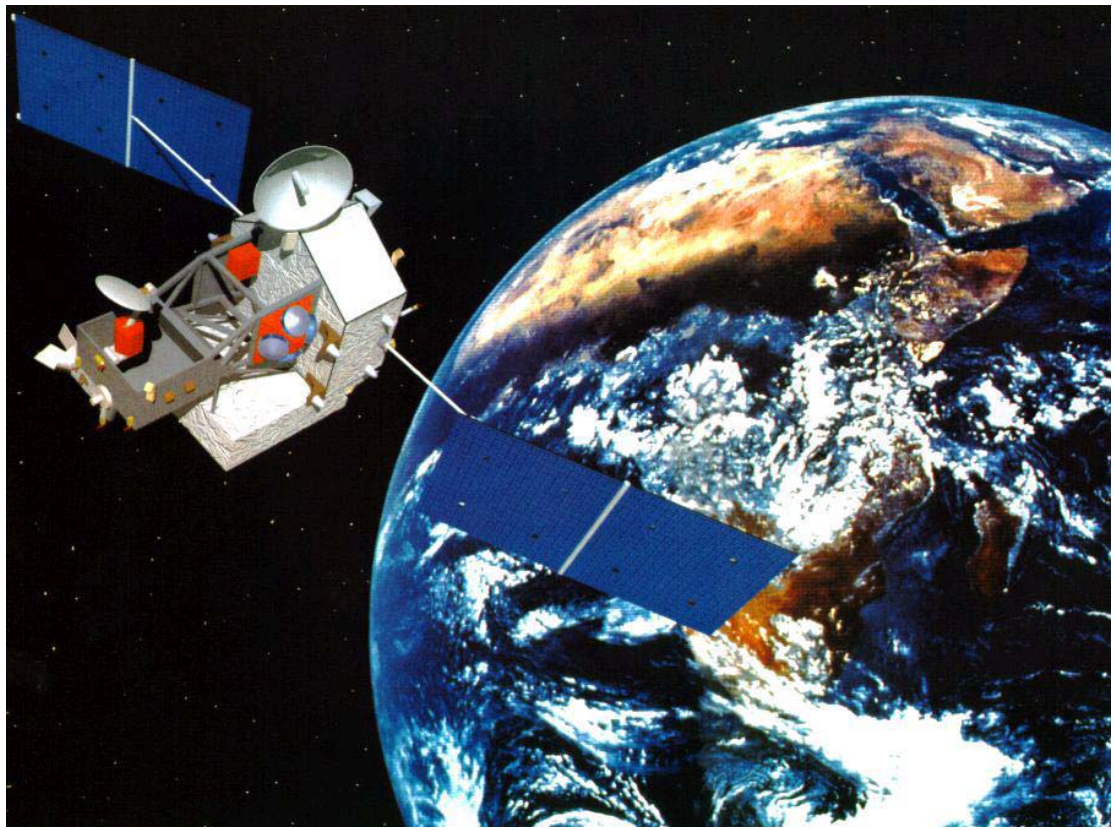
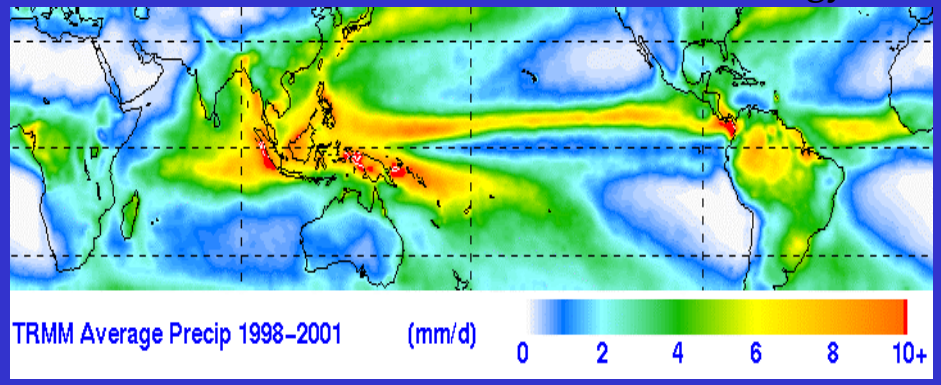


Tropical Rainfall Measuring Mission (TRMM)

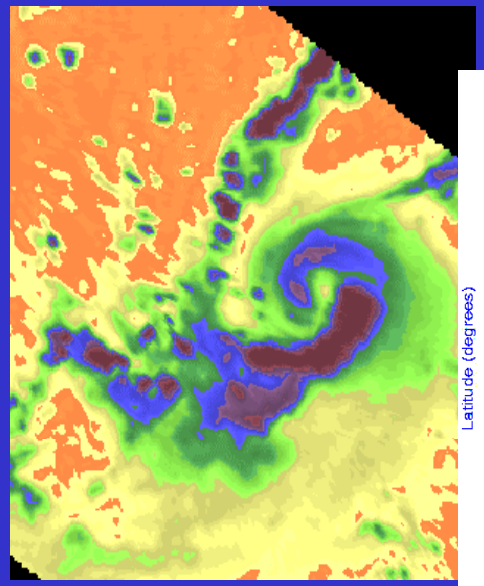
- Nov. 1997 launch, 35° inclination; 402 km, Precipitation Radar (PR), TRMM Microwave Imager (TMI), Lightning Sensor, Vis./IR Imager

- <u>Science</u>
  - First space radar and radiometer observation of precipitation leading to improved climatology of Tropical precipitation, monitoring of ENSO variations and definition of rainfall diurnal cycle
  - Unique, fine-scale hurricane/typhoon structure information linked to rapid intensification
  - Improved global modeling of hydrologic cycle and storms through assimilation of precipitation information
  - First Sea Surface Temperature(SST) Measurements through clouds
  - Aerosol/pollution impact on precipitation determined for first time
  - Lightning/convection relation quantified for land and ocean
  - Calibration of long-term satellite precipitation data set and multi-satellite, 3-hr analysis

Five-Year TRMM Rainfall Climatology

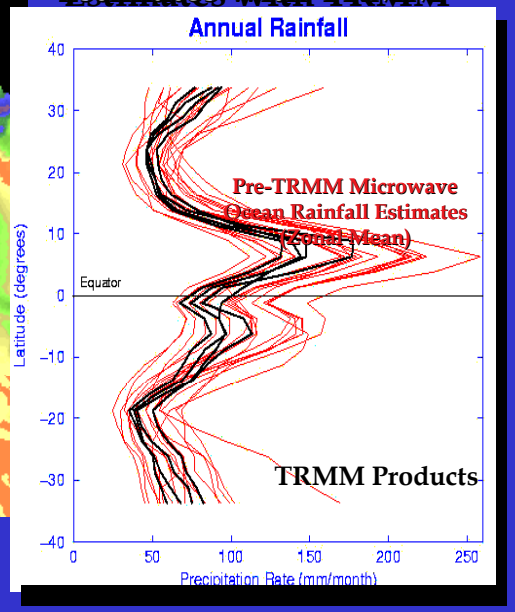


January 1998 - December 2002



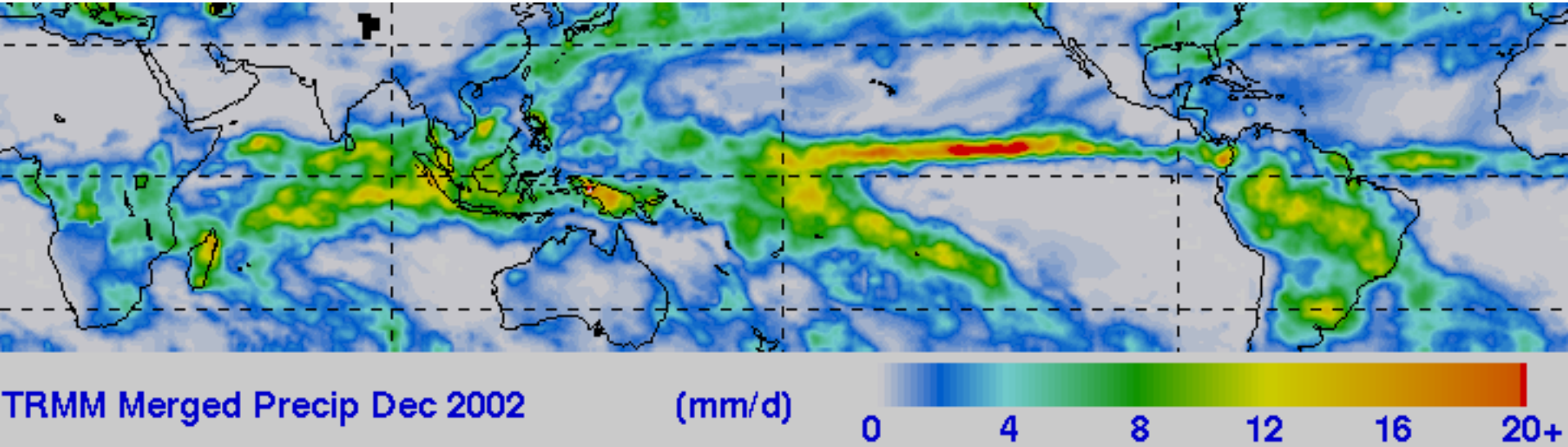
Typhoon Damrey

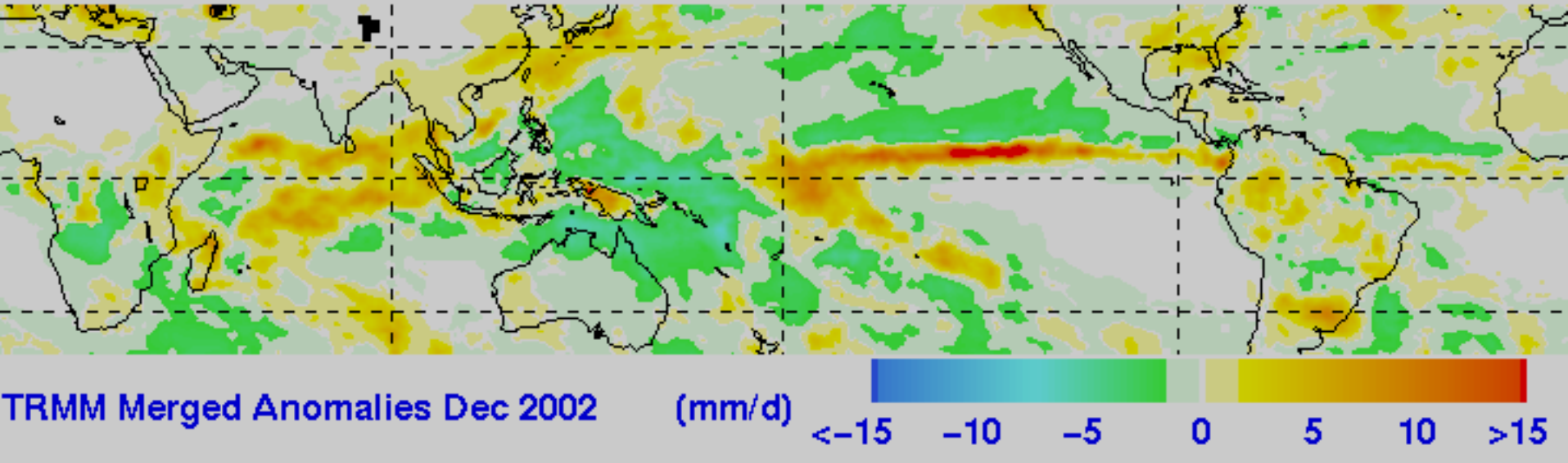
Improved Ocean Rain Estimates with TRMM



December 2002 TRMM Rainfall and Anomalies

El Nino Signature continues in West and Central Pacific

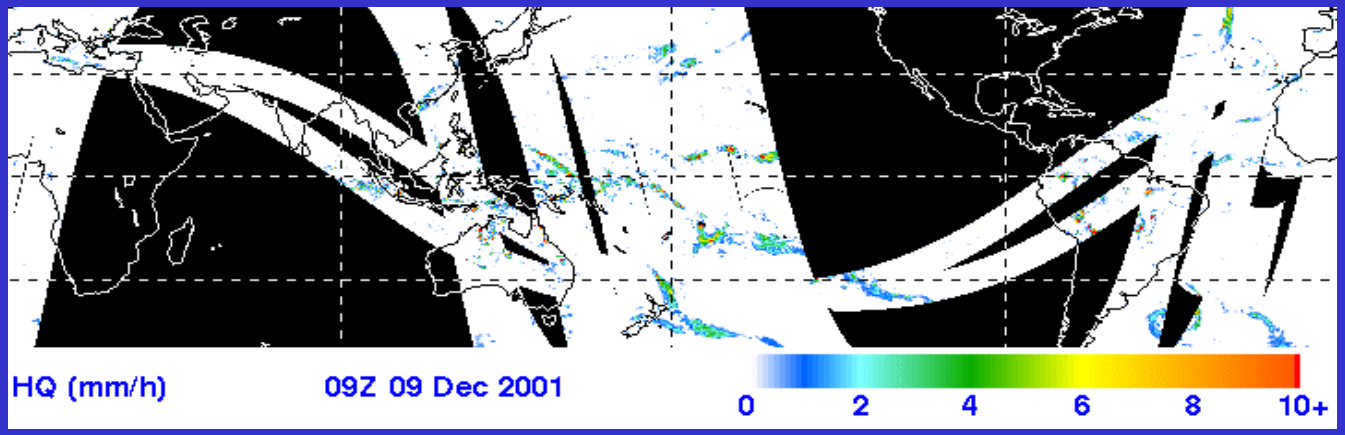




TRMM Multi-Satellite Real-Time Precipitation Estimates

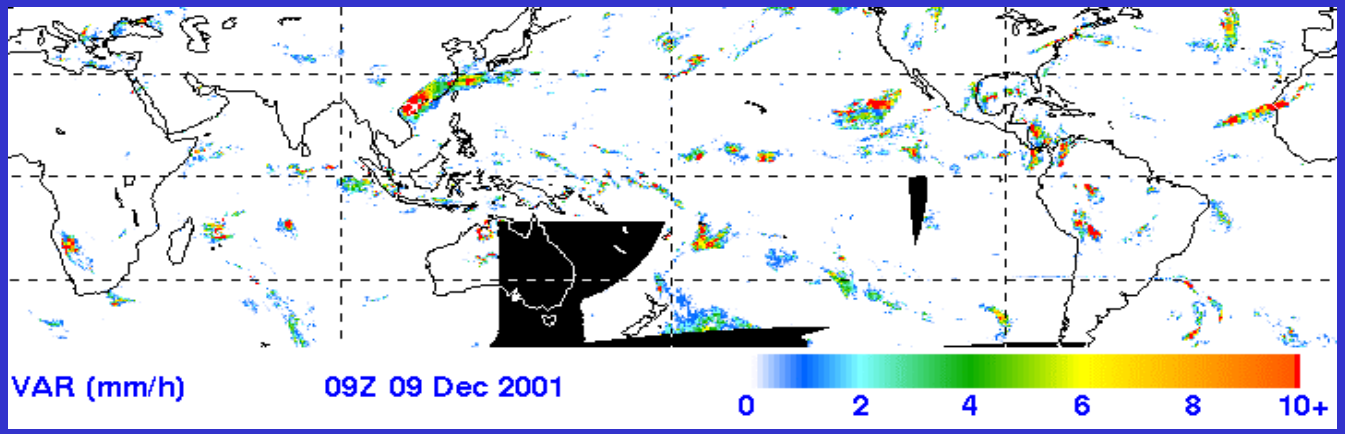
3B40RT

Combined microwave (TRMM and TRMM-calibrated SSM/I)



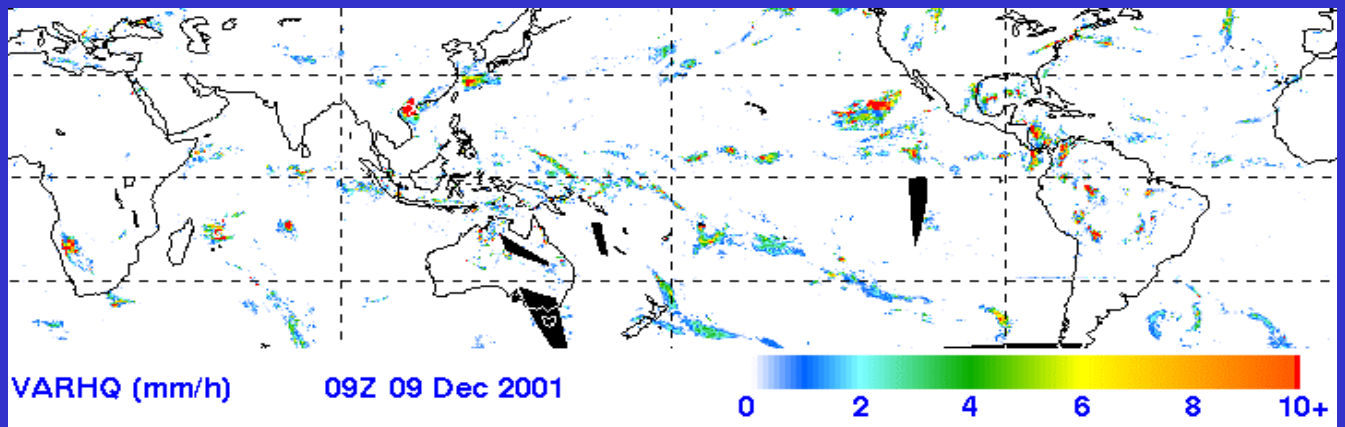
3B41RT

Microwave-calibrated geo-IR estimate



3B42RT

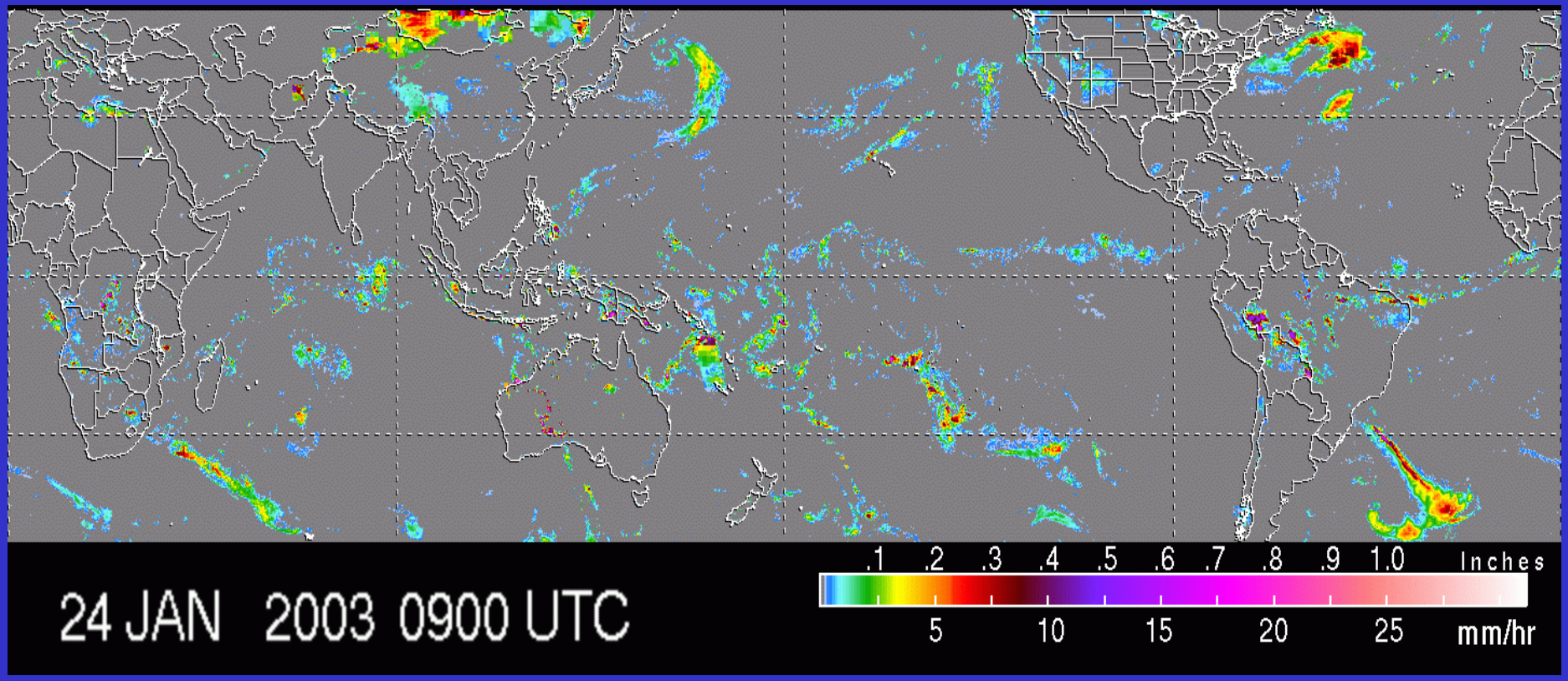
Merged microwave and geo-IR estimates



Adler/Huffman

Tropical Rainfall Measuring Mission (TRMM)

TRMM Multi-Satellite Real-Time Precipitation Estimates (3-hr interval)

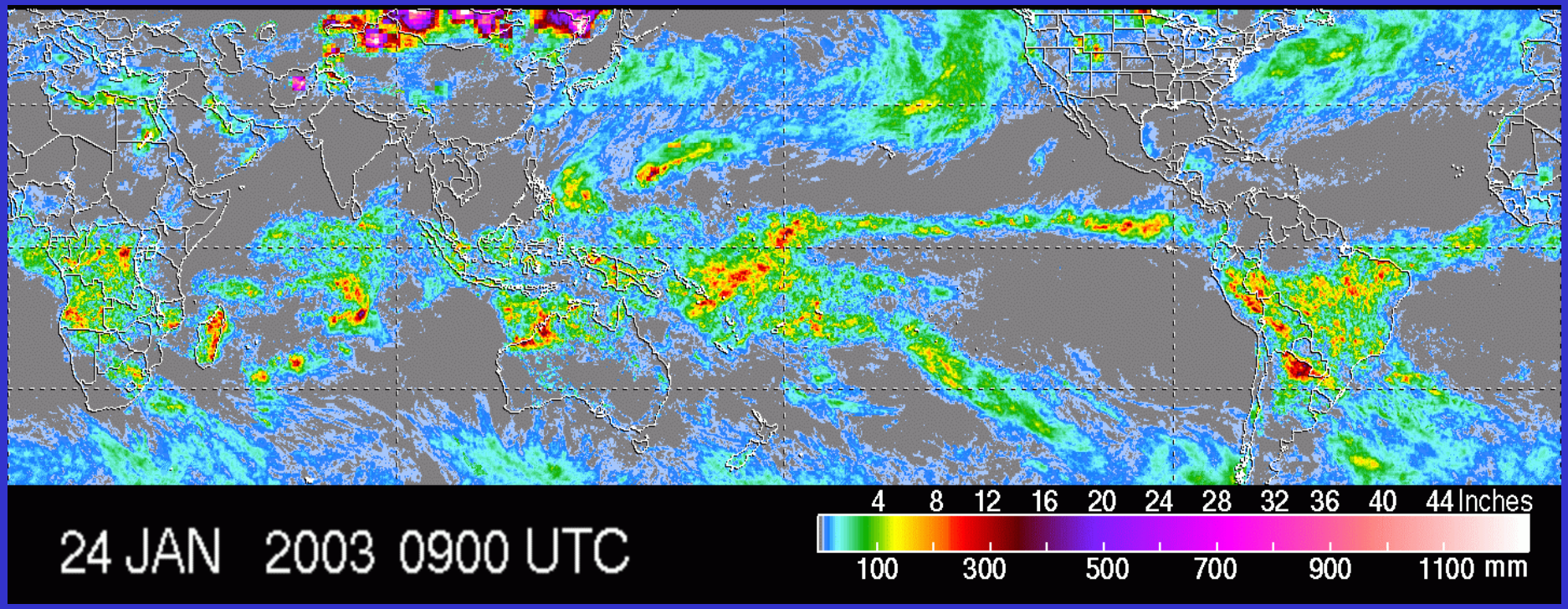


- Near global merged precipitation estimates using TRMM, polar-orbit microwave, and geosynchronous-IR data (NOAA/CPC merged IR product)
- Bias removal relative to TRMM via histogram matching (30 day trailing window)
- 3-hr, 50°N-S; 0.25°x0.25° lat./long. grid; available 4-hr after real time

(available via ftp; see U.S. TRMM web site[trmm.gsfc.nasa.gov])

TRMM Multi-Satellite Real-Time Precipitation Estimates (3-hr interval)

Seven Day Accumulation



- Near global merged precipitation estimates using TRMM, polar-orbit microwave, and geosynchronous-IR data (NOAA/CPC merged IR product)
- Bias removal relative to TRMM via histogram matching (30 day trailing window)
- 3-hr, 50°N-S; 0.25°x0.25° lat./long. grid; available 4-hr after real time
- Additional satellite data will be added (AMSR-E, AMSR on ADEOS II, AMSU)

(available via ftp; see U.S. TRMM web site[trmm.gsfc.nasa.gov])

Issues Related to TRMM Re-entry from a Science Perspective

- Re-entry discussion initiated by TRMM exceeding 1/10,000 threshold (TRMM is 2/10,000 and an estimated debris x-section of 11 m^2 vs. threshold of 8 m^2)
- About 100-200 uncontrolled re-entries of large, artificial objects per year, perhaps 50 or so the size of TRMM
- TRMM has evolved from research mission to monitoring mission so that length of record is important for research and data is critical for quasi-global rainfall monitoring in real-time
- Compelling science reason for continuation of TRMM is need for **radar** in detecting global precipitation trends--extended TRMM mission lengthens record and provides possible overlap with GPM radar
- Operational value of TRMM in reducing risk of injury/death is fairly obvious (e.g., better hurricane/typhoon forecasting), but difficult to quantify
- NASA HQ Code Q report indicates that TRMM controlled re-entry is not required and that decision is up to Code Y

TRMM Risk/Benefit Workshop (June 2001)

Independent Panel

Roger Pielke, Jr. (U. of Colorado)

(Findings on TRMM Operational Use)

Finding 1.1. All workshop participants agreed that the TRMM data are now being, and will continue through the remaining lifetime of the mission to be, used by agencies in the US and abroad to aid operational marine forecasting, especially in the data-sparse Pacific and Indian Oceans.

Finding 1.2. Participants agreed unanimously that the risk to human life of not having TRMM data available for operational uses cannot presently be accurately quantified.

Finding 1.3. Most, but not all, workshop participants subjectively estimated that the risk to human life of an uncontrolled reentry would be exceeded by the risk to human life of not having TRMM data for operational uses.

Operational value of TRMM in Hurricanes and Typhoons

- Approximately 15,000 deaths annually during the 1990's due to hurricanes/typhoons
- Comment from DoD Joint Typhoon Warning Center (JTWC) : "JTWC has been using TRMM data since 1998. On several occasions, TRMM passes over a TC led to storm relocation and changes in intensity for our typhoon warnings. JTWC and the Air Force Weather Agency, which also provides fixes for our AOR, combined to issue over 150 real-time TRMM fixes worldwide during 2000. TRMM data is integral to JTWC's TC reconnaissance and warning mission. We'd like to have this data available as long as possible." Lt. Col. Mark Zettlemoyer (Director, Joint Typhoon Warning Center)
- Research at Goddard and Florida State indicates improved hurricane/typhoon forecasts due to assimilation of TRMM rainfall information into models. TRMM data being used operationally at US and European numerical forecast centers.

NASA HQ (Code Q) TRMM DISPOSAL RISK REVIEW REPORT

- A 15 page report was issued in September, 2002 by the NASA HQ Office of Safety and Mission Assurance (Code Q) to the HQ Earth Science Enterprise(Code Y) that discusses the various aspects of TRMM re-entry
- Quote from p. 9 of report:

  "Since the estimated casualty risk of a TRMM uncontrolled reentry is approximately 1 in 5000 events, the public safety benefits from an extra five years of data can be very small and still provide a reasonable justification for extending the mission. For example, TRMM data saving just one life over a 5 year extended mission could be traded against the risk of only 1/5000th of a reentry casualty caused."
- Quotes from the Summary of the report :

  "In the case of a TRMM uncontrolled reentry, the casualty risk of 2/10,000 events appears to fall into an intermediate, or tolerability zone, where the risk may be tolerated in return for other (public safety) benefits."

  "Barring any impediments from NASA Legal Council, it is concluded that a decision to accept the uncontrolled reentry public safety risk of TRMM, in exchange for extending the mission and potentially benefiting from the improvement in storm analysis and forecasting capabilities, is reasonable and within the discretion of the Earth Science Enterprise and the NASA Administrator."

Summary

- TRMM Project Scientist believes that a TRMM controlled re-entry would not provide a **significant** increase in safety, due to ~50 other uncontrolled re-entries per year
- TRMM **radar data** required to detect global precipitation trend--compelling scientific reason to continue TRMM
- TRMM data is being used in operational weather forecasting in ways that indicate that lives are being saved
- TRMM is a near-perfect operating mission and a science, applications, engineering, data system and international cooperation success
- Code Q report indicates that TRMM controlled re-entry is not required by Code Q; decision up to Code Y

TRMM is $750M investment (U.S. and Japan)

Science During TRMM Descent from 402 to 320 km

- Continued monitoring using PR, TMI, VIRS, and LIS--all instruments on
- Standard products from PR will not be automatically produced during descent, except at 350km; however, valuable information will be retrievable from PR at various times and altitudes
- "Extra" months of data (during descent) valuable for trends, inter-annual variations (e.g., El Nino) and additional observations of tropical cyclones and other systems
- Operational use of all data (except from PR) will continue to be valid
- Deep space look maneuver for TMI and VIRS requested to be carried out during descent
- Possible 90º yaw maneuver for PR; NASDA will be queried