National Aeronautics and Space Administration

TRMM, Hydrologic Science, and Societal Benefit: The Role of Satellite Measurements

Michael H. Freilich   TRMM 15th Anniversary Symposium   12 November 2012

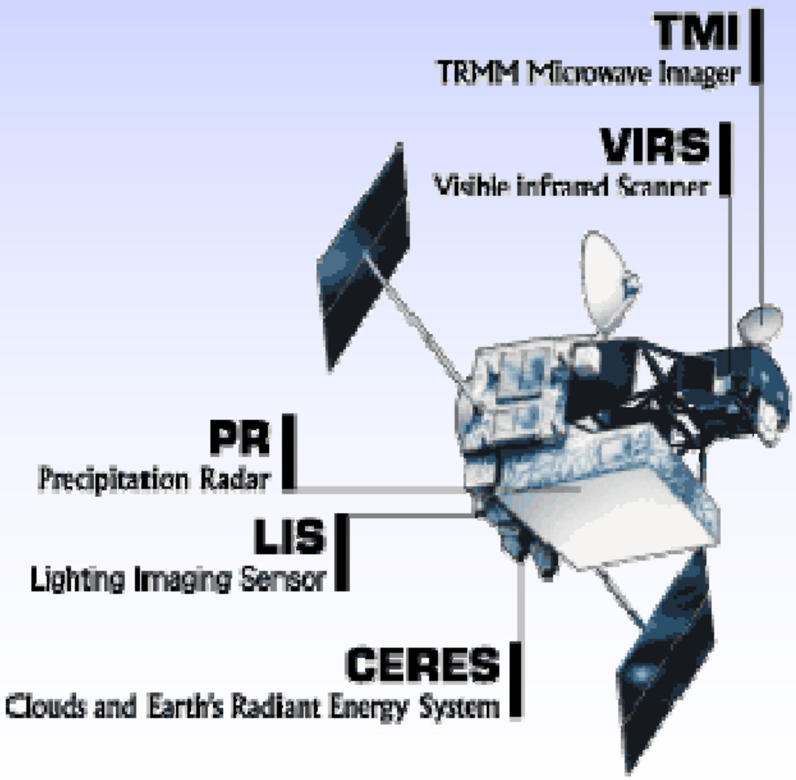
KEY TRMM ATTRIBUTES

- **Long on-orbit lifetime – 15 years to date**
- **Inclined orbit provides frequent sampling and resolves the diurnal cycle**
- **Suite of complementary, active and passive instruments enables 3-D, simultaneous measurements of quantities important for understanding precipitation processes and context**
- **Free and open data policy allows broad scientific use and construction of unique multi-instrument, multi-mission products**
- **Near-real-time data availability allows TRMM research observations to contribute to “operational” prediction/monitoring and direct societal benefit**

- ***TRMM’s strong, substantive scientific and mission collaboration between JAXA and NASA provides the foundation for GPM and other future international space-based monitoring systems***

Tropical Rainfall Measuring Mission (TRMM)

- **Science Objective:** ***Advance <u>knowledge of global water and energy cycles</u> through observed time and space distributions of <u>tropical rainfall, hydrometeor structure and latent heating</u>.***
- **Approach:** ***Accurate estimation of precipitation characteristics through first-time use of <u>passive and active microwave instruments</u>.***

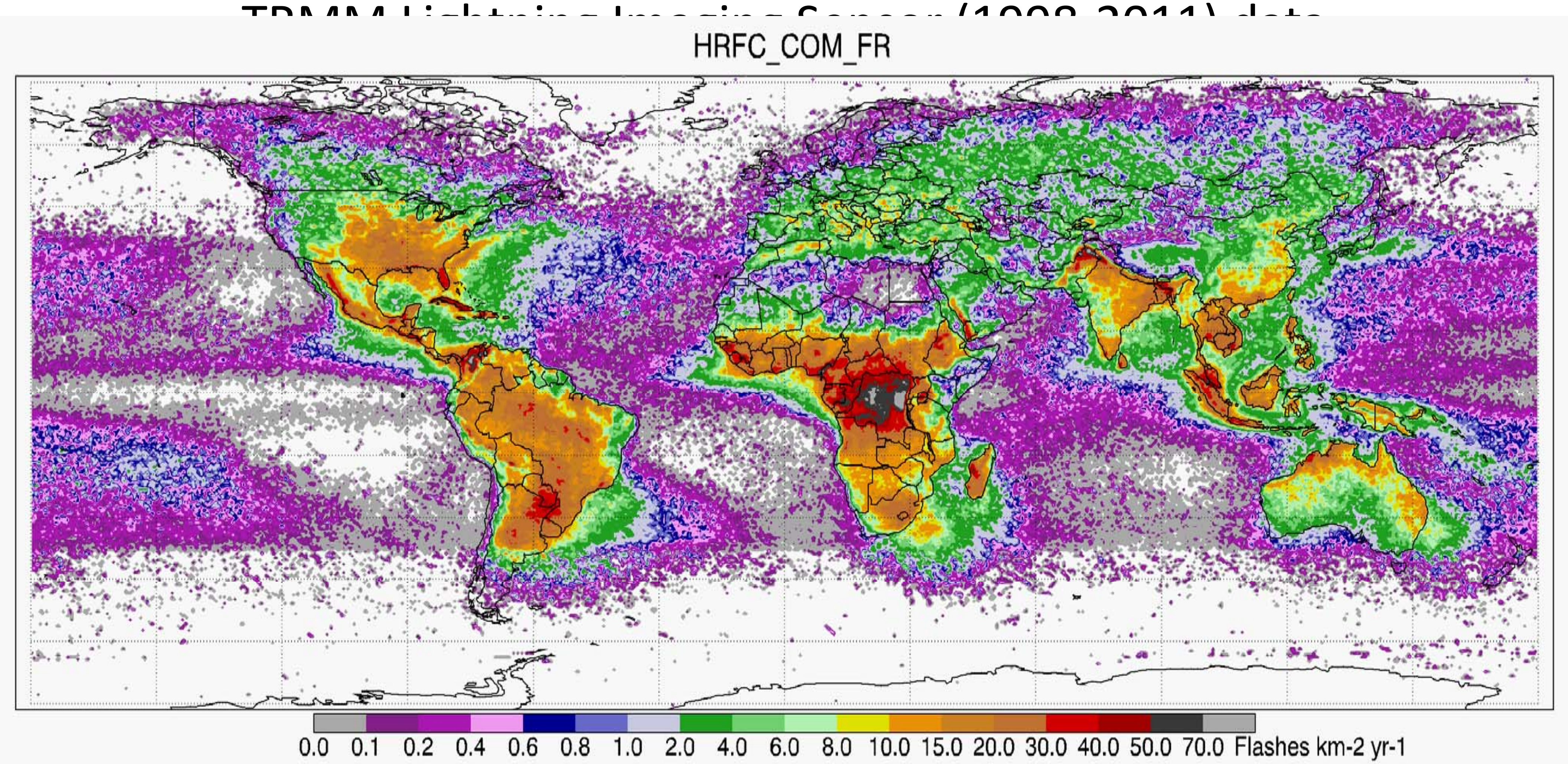


- **Joint NASA/JAXA mission launched in Nov. 1997 into inclined (35º) orbit; spacecraft and instruments in excellent condition**
- **Instrument Payload:**
  - **TRMM Microwave Imager (TMI)**
    - **10, 19, 37, 86 GHz, conical scanning**
  - **Precipitation Radar (PR) [Japan/CRL]**
    - **14 GHz, cross-track scanning**
  - **Lightning Imaging Sensor (LIS) [MSFC]**
    - **Staring optical array**
  - **Visible IR Scanner (VIRS)**
    - **5-channel, cross-track scanning**
  - **Cloud & Radiant Energy System (CERES) [LaRC]**
    - **Radiation budget (failed after 6 mos.)**

TRMM Tropical Rainfall Measuring Mission

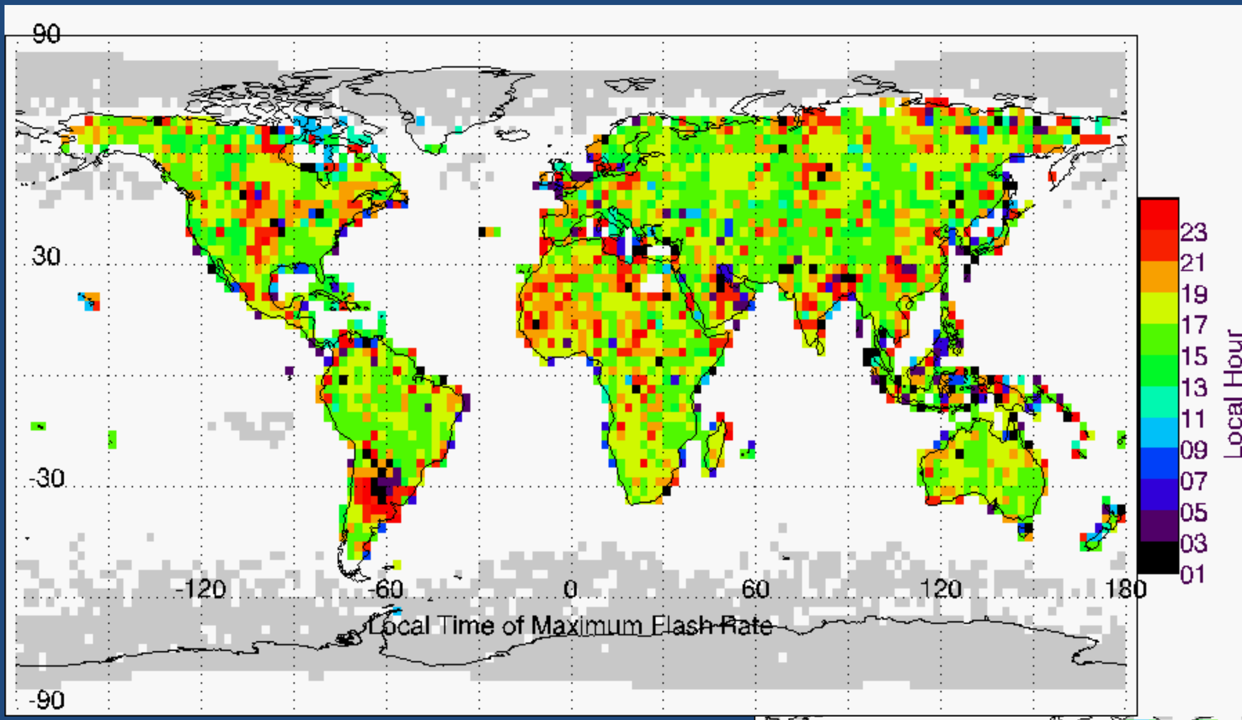
Annual Global Lightning Climatology (0.5°)

from combined Optical Transient Detector (1995-2000) and TRMM Lightning Imaging Sensor (1998-2011) data

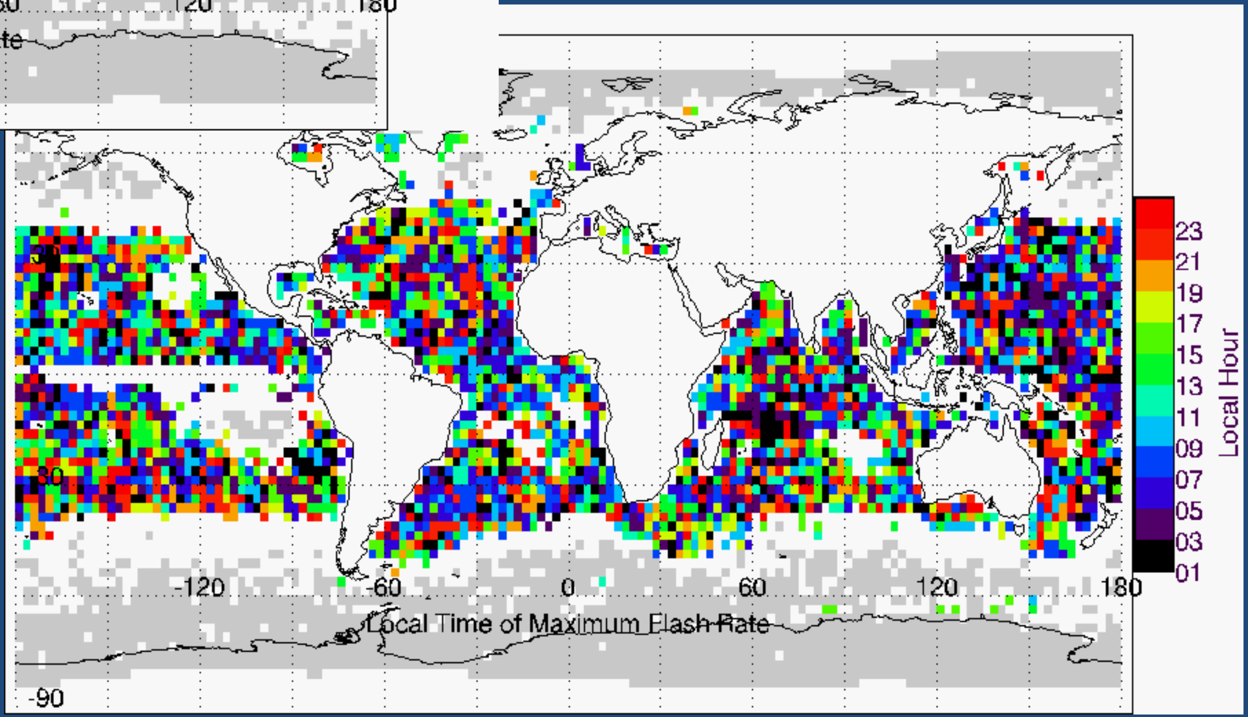


Cecil, D.J., D.E. Buechler, and R.J. Blakeslee, 2012: Gridded Lightning Climatology from TRMM-LIS and OTD: Dataset Description. Atmospheric Research, in press

Local Time of Peak Diurnal Lightning Rates around the Earth

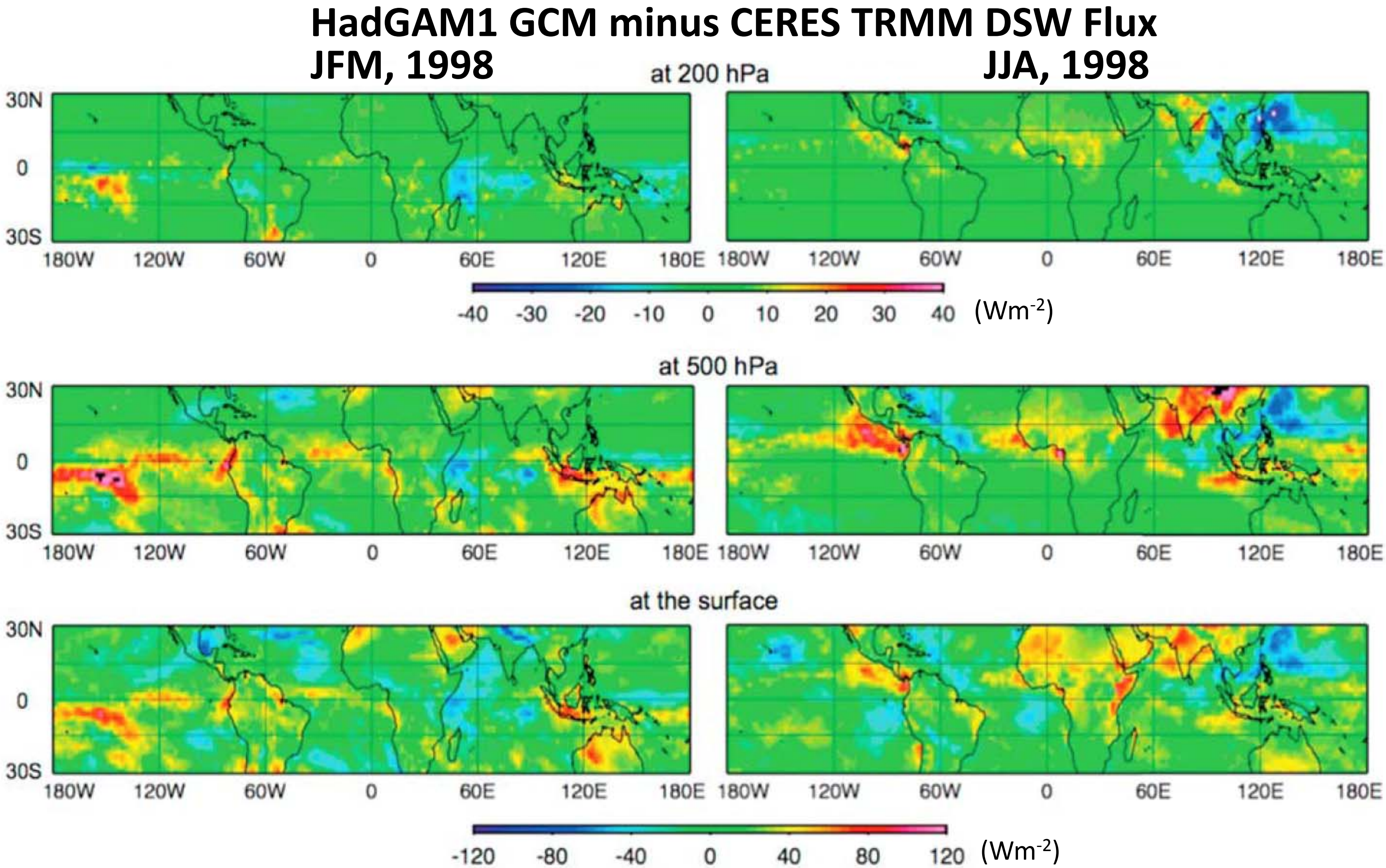


Land



Ocean

CERES and VIRS TRMM Data Show GCM Overestimates Downwelling Shortwave Radiation in Upper Troposphere due to Lack of Clouds in Model



- Radiative flux profiles are derived from combined CERES and VIRS TRMM measurements.

- Downwelling SW radiative flux differences suggest the HadGAM1 GCM generally under-estimates cloud amounts between 200 and 500 hPa.

=> Mid-tropospheric cloud amounts are underestimated in the central Pacific Ocean during the peak of the El Niño event in JFM 1998, as well as in the Indian Monsoon and east Pacific Ocean regions in JJA 1998.

Su et al., J. Geophys. Res. (2010)

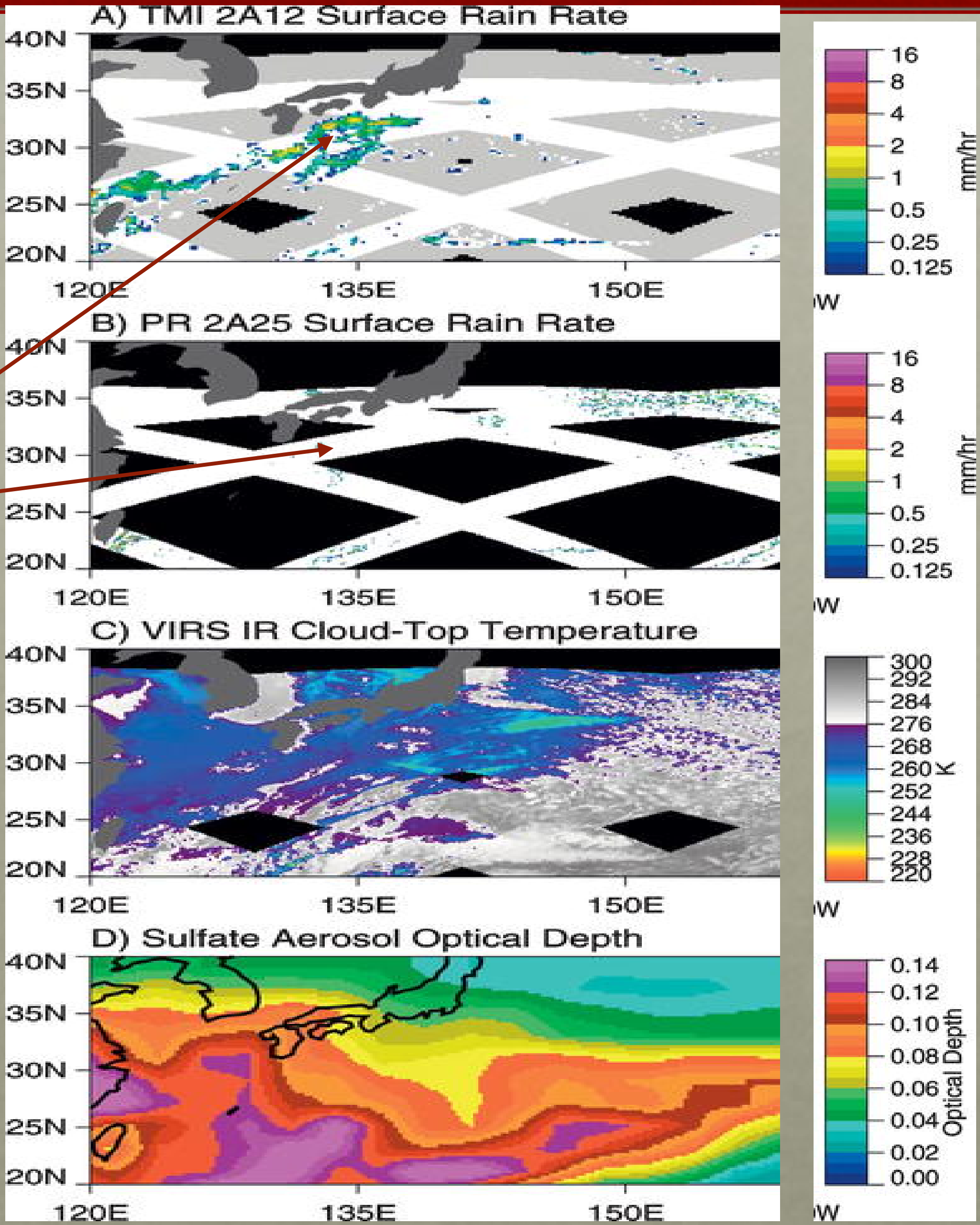
The Importance of Radar and Passive Microwave on the Same Satellite

Remaining Differences between Passive Microwave and Radar Retrievals --an extreme example

TMI shows significant rain area, but PR shows very little

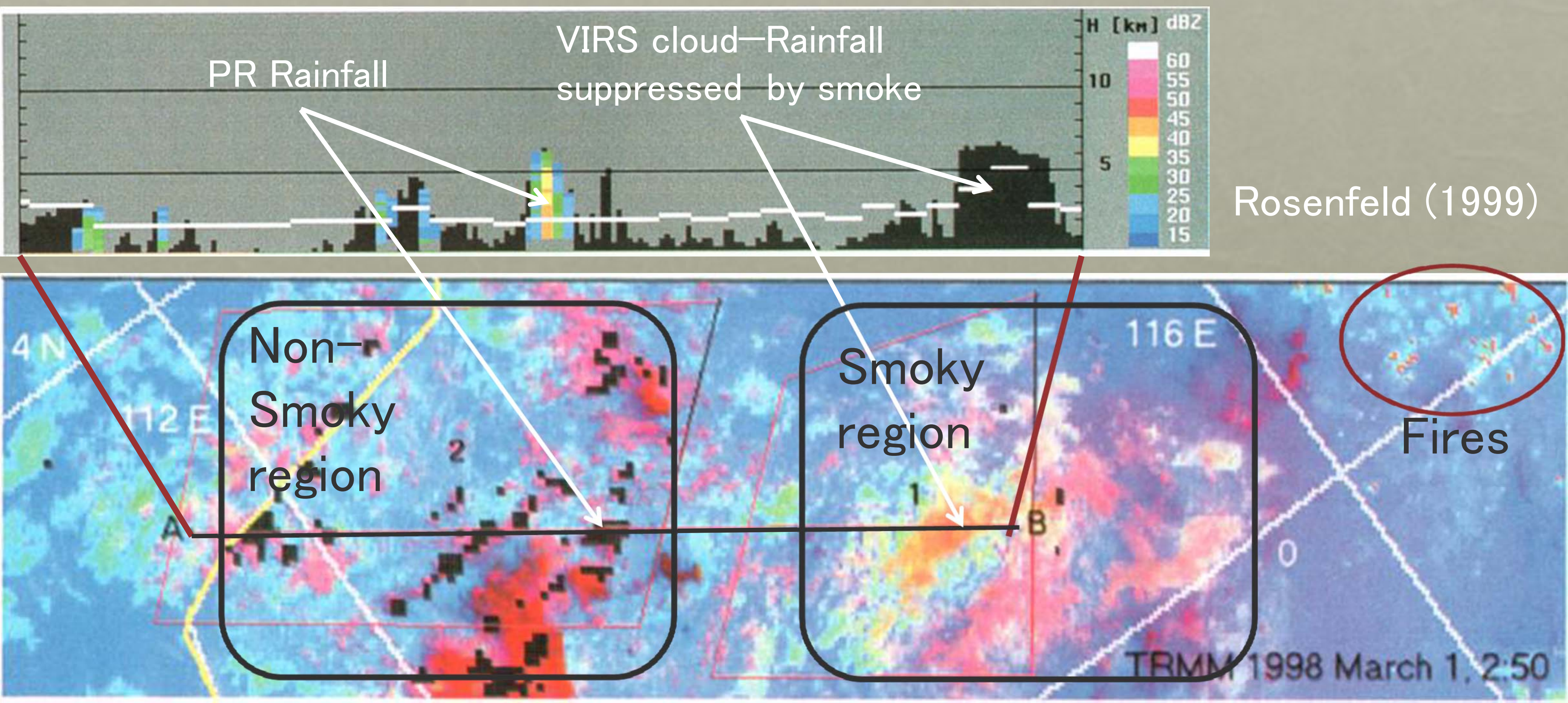
Result probably due to aerosol effects on size distribution of cloud/rainfall droplets (high cloud liquid water content, but small amount of rain).

From Berg et al., 2006

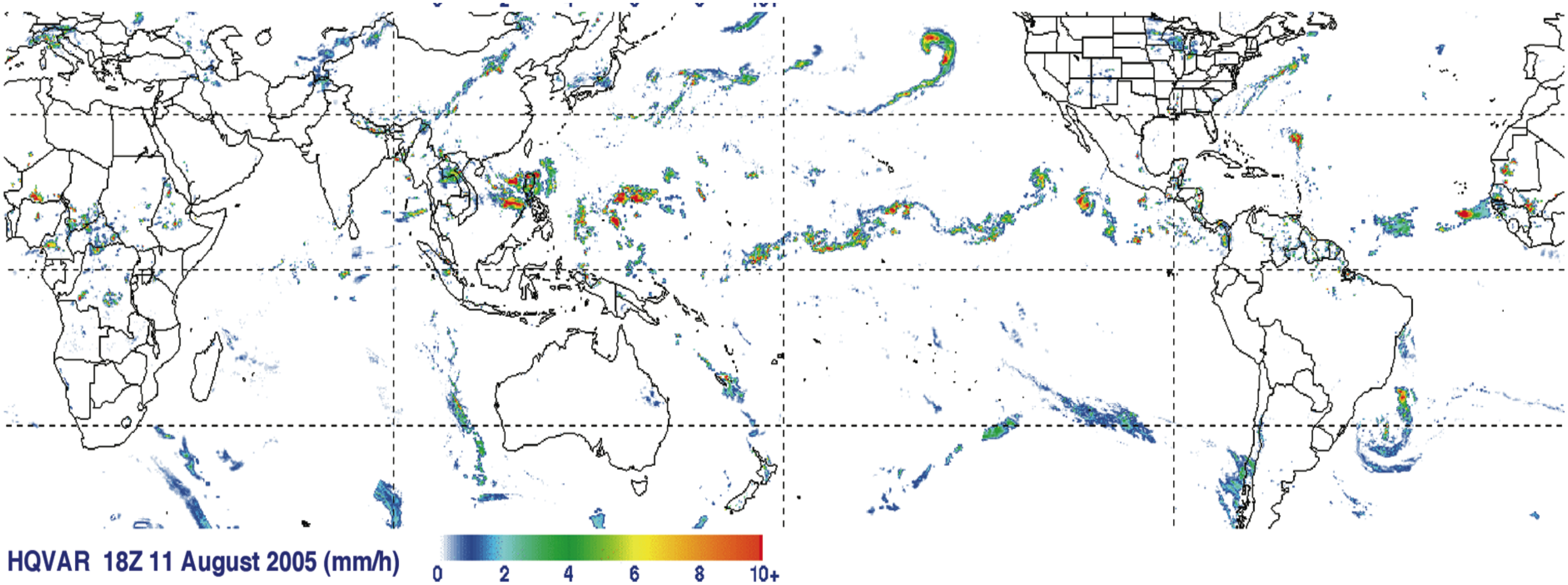


Precipitation Suppression by smoke

TRMM VIRS and PR data shows suppression of precipitation formation in clouds impacted by smoke aerosols.



TRMM Multi-Satellite Precipitation Analysis (TMPA/3B42)



- 3-hr, 0.25^{o} lat/lon resolution
- Polar-orbit passive microwave with gaps filled by geo-IR estimates – **all calibrated by TRMM**
- Near-real-time product (~6 hrs. after observations); Research product (incorporating monthly gauges over land)
- Used in > 200 journal publications; *most widely downloaded TRMM product*

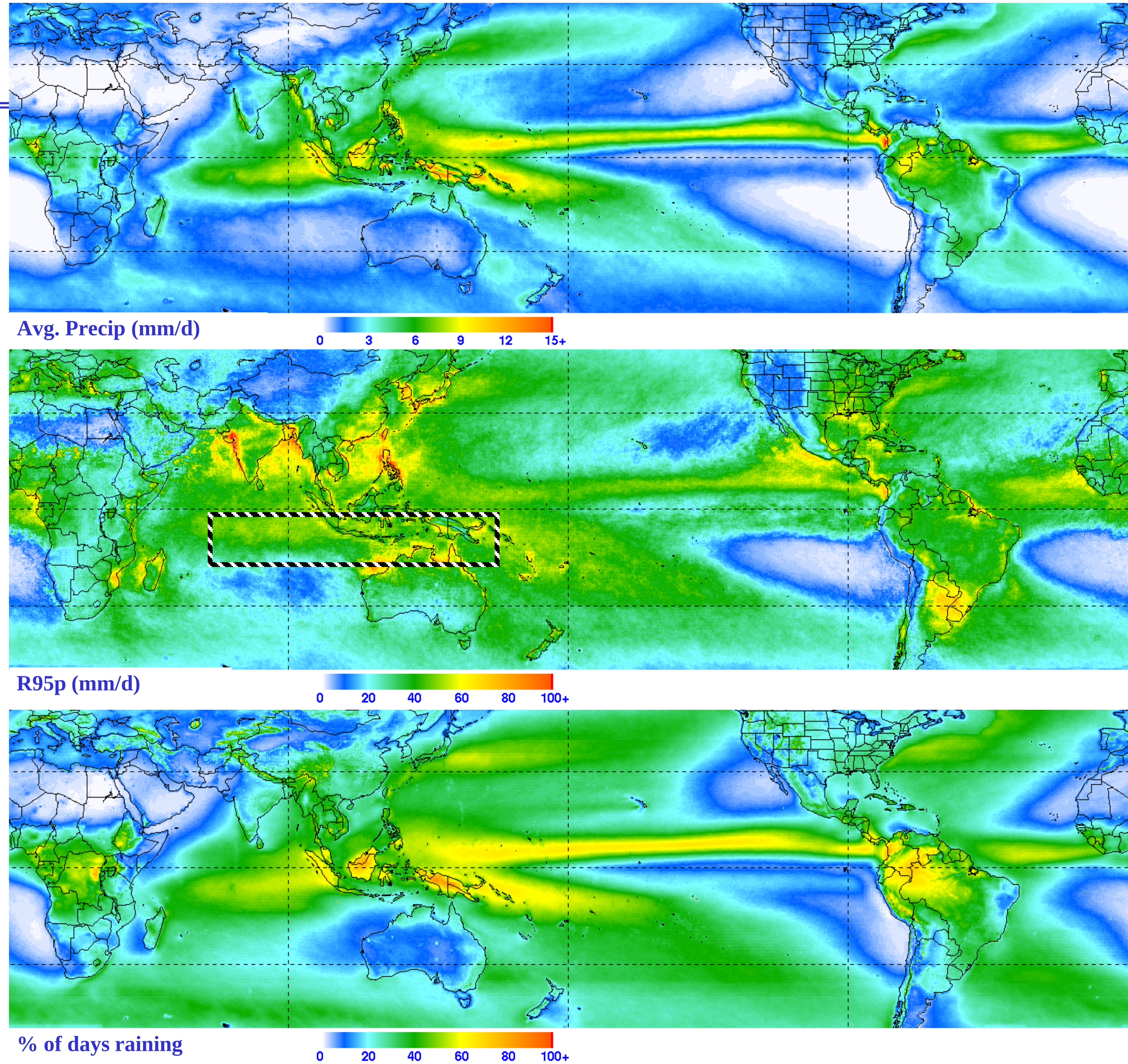
Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: **The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale.** *J. Hydrometeor.*, **8**(1), 38-55.

RESULTS – Quasi-global TMPA 1998-2008 “Climatology”

Interesting variations:

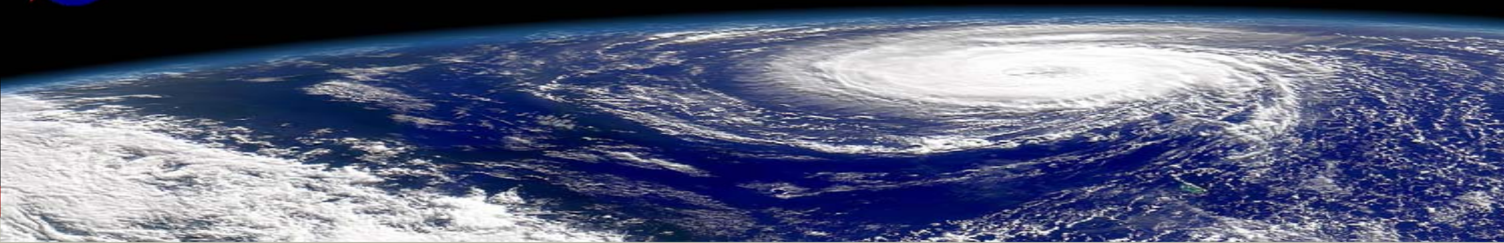
- extra R95p maxma north-west of Australia, south-west of Mexico
- SPCZ gradient in Avg. Precip not reflected in R95p
- flip-flop of Avg. Precip and R95p in South America
- % of days raining high upper reaches of

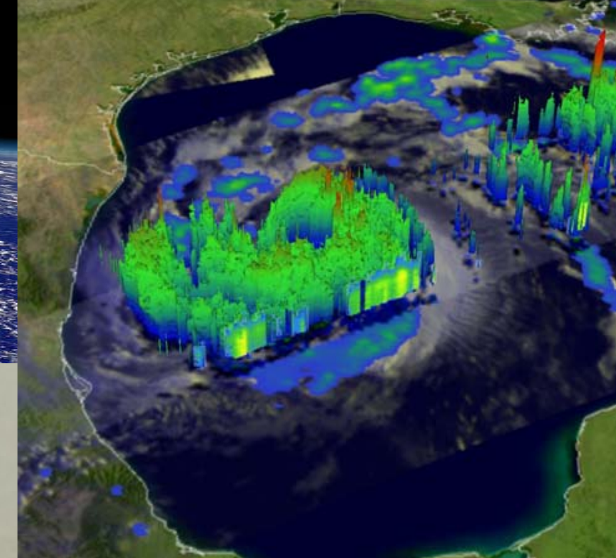
- most of these effects persist through the seasons



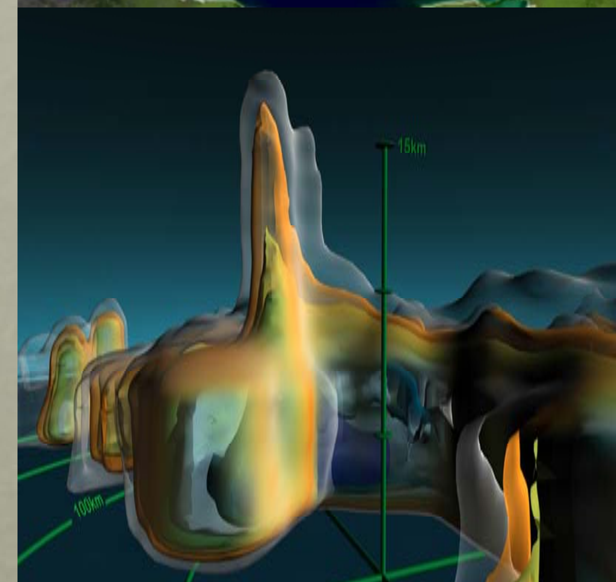
Asian Monsoon

TRMM and *Hurricanes*

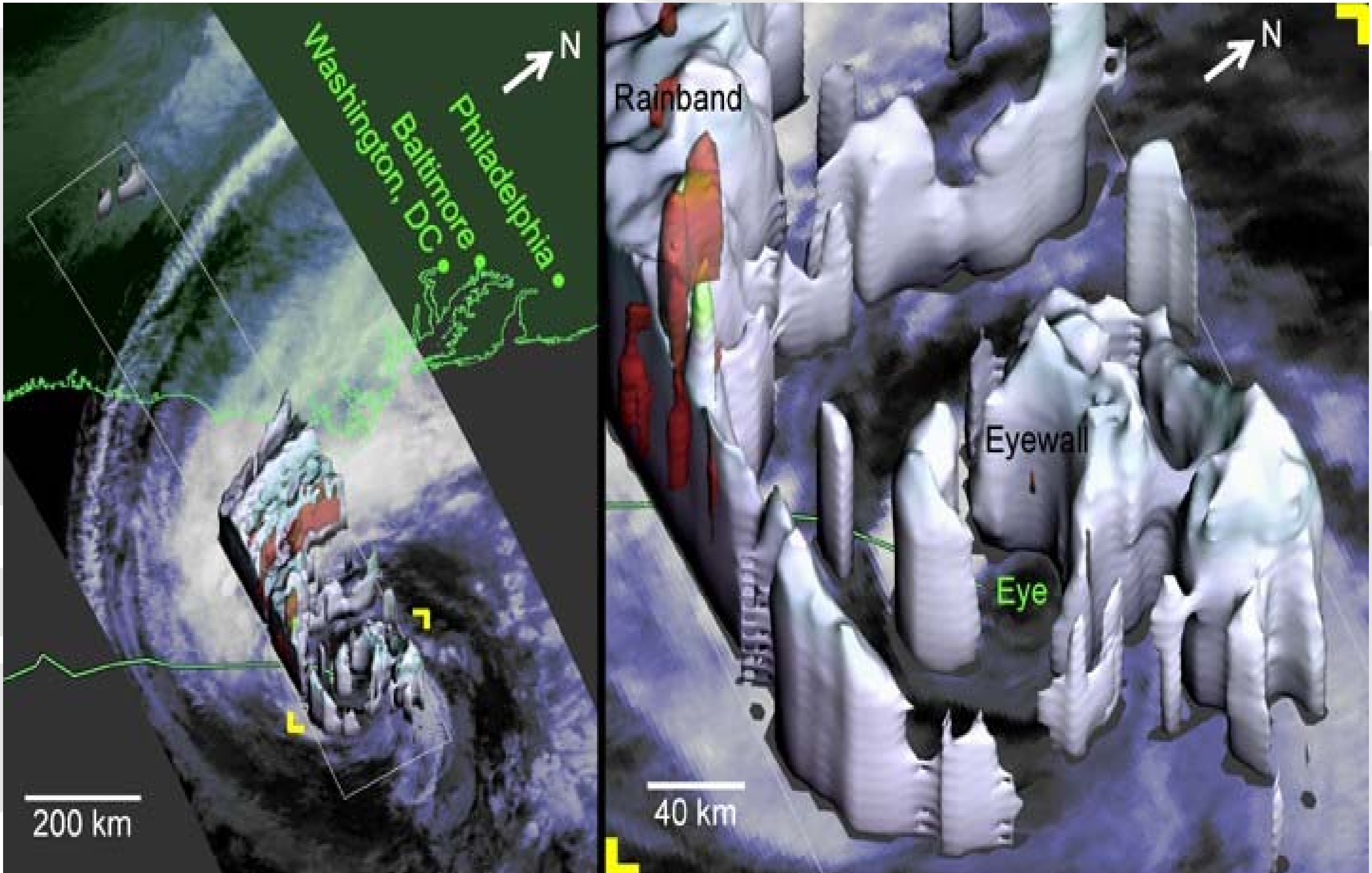




- Rainfall climatology for hurricanes
- Detailed rainfall structure and lightning in eye wall and rainbands
- The role of "hot towers" in storm intensification
- Rainfall accumulations and monitoring of flood/landslide potential
- Improved simulations of hurricanes
- Provides ~600 estimates of storm center position per year globally

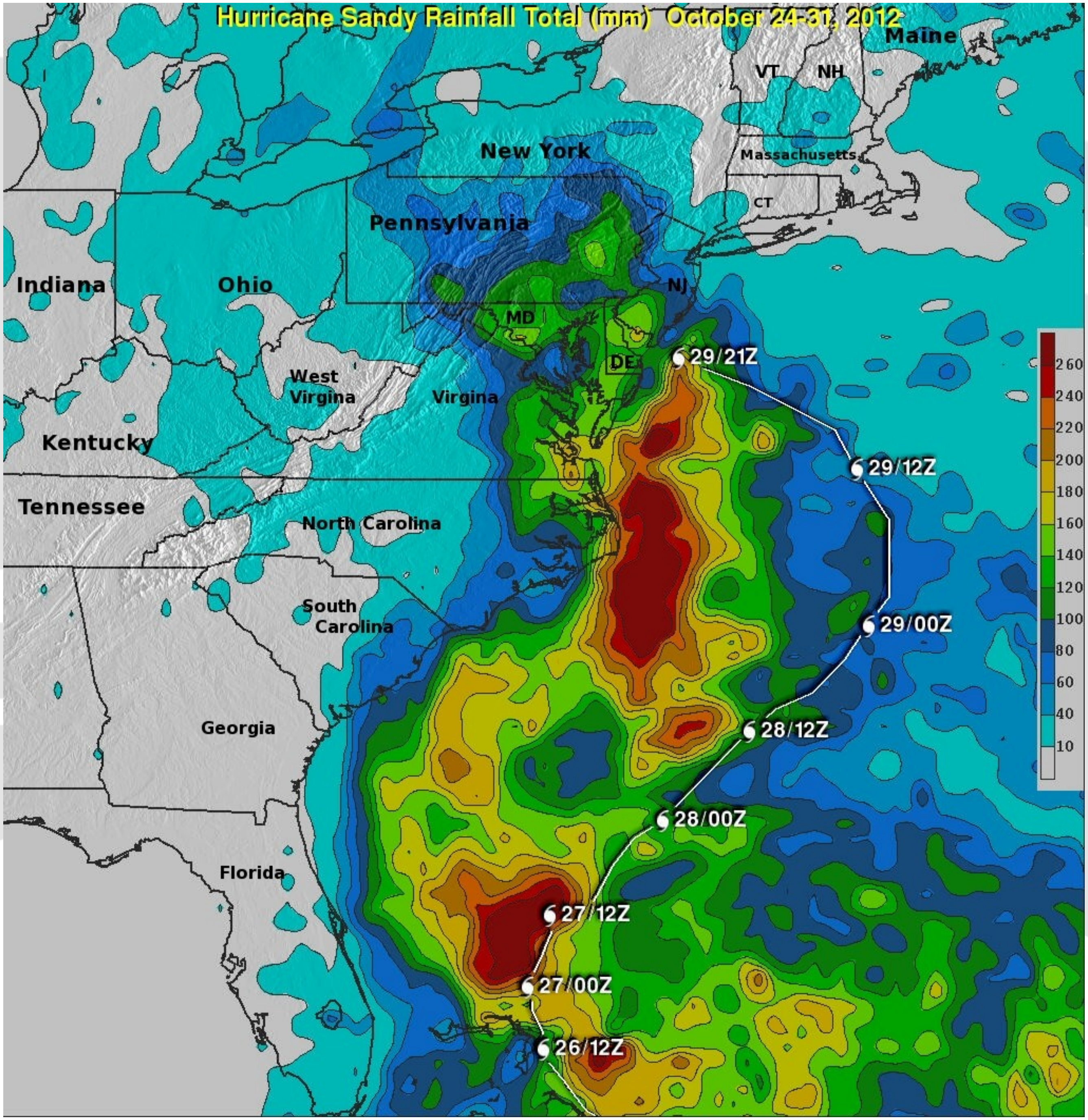


TRMM Observations of Super-Storm Sandy

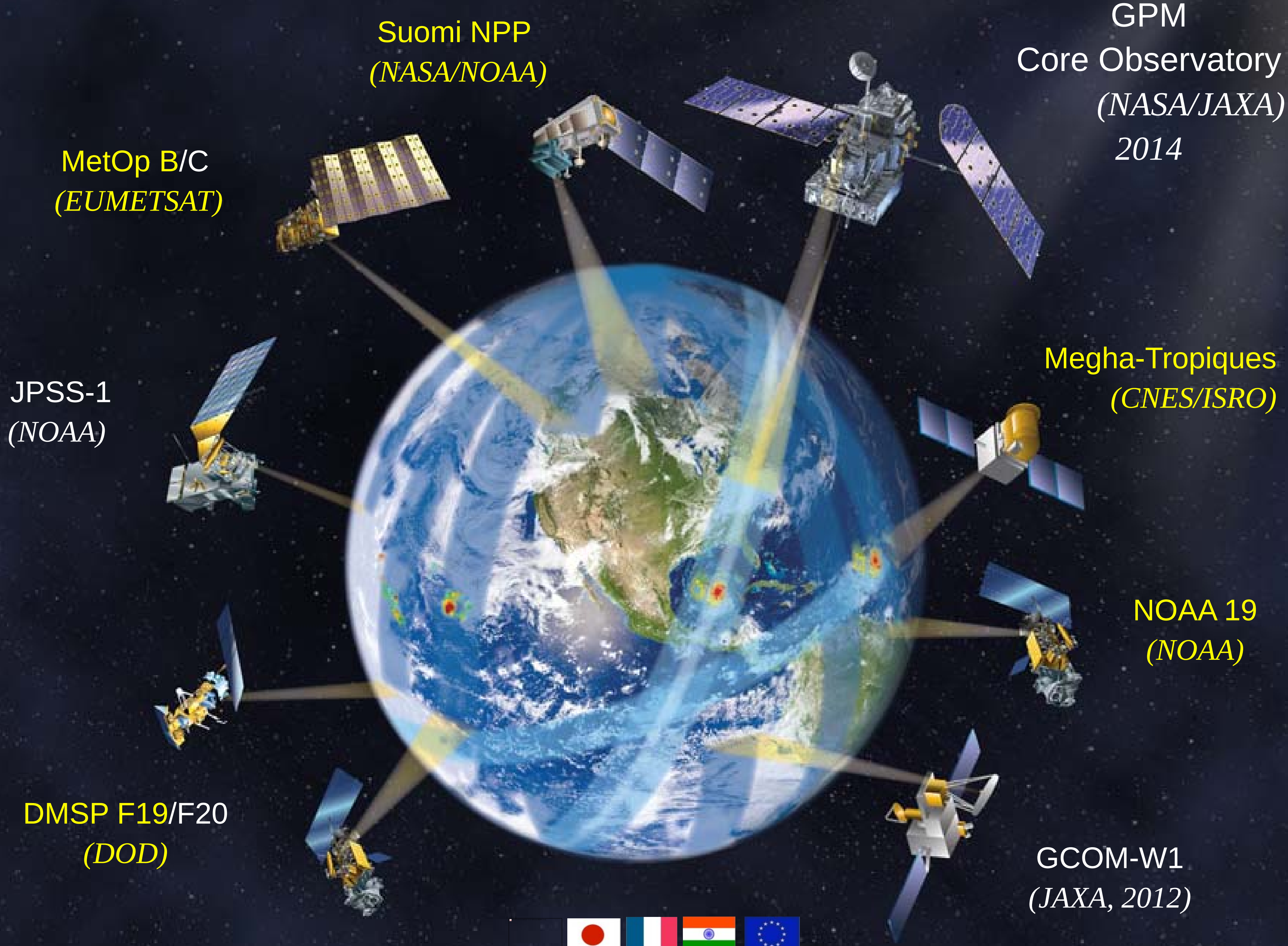


Hurricane Sandy observed by the TRMM Precipitation Radar at 2:20 EDT on 28 October 2012

TRMM Observations of Super-Storm Sandy



GPM Constellation of Satellites

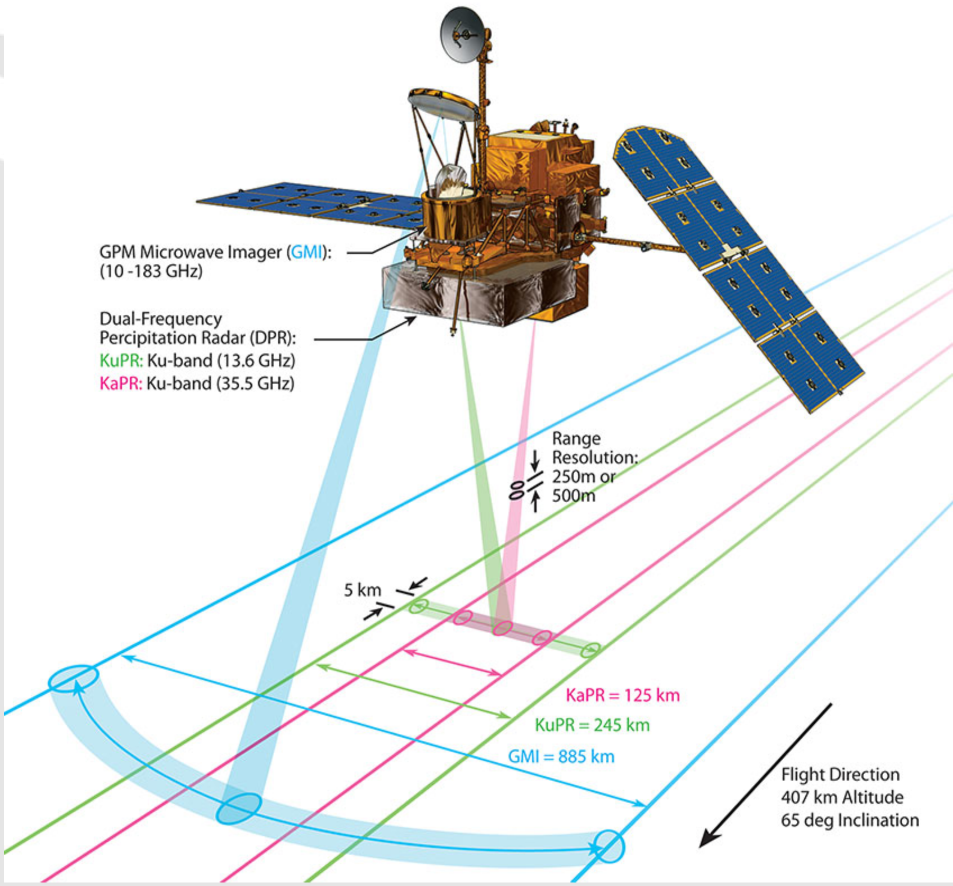


Next-Generation Unified Global Precipitation Products Using GPM Core Observatory as Reference

GPM Measurement Capabilities LRD 2014

Dual-Frequency (Ku-Ka band) Precipitation Radar (DPR):

- *Increased sensitivity (~12 dBZ) for light rain and snow detection relative to TRMM*
- *Better measurement accuracy with differential attenuation correction*
- *Detailed microphysical information (DSD mean mass diameter & particle no. density) & identification of liquid, ice, and mixed-phase regions*



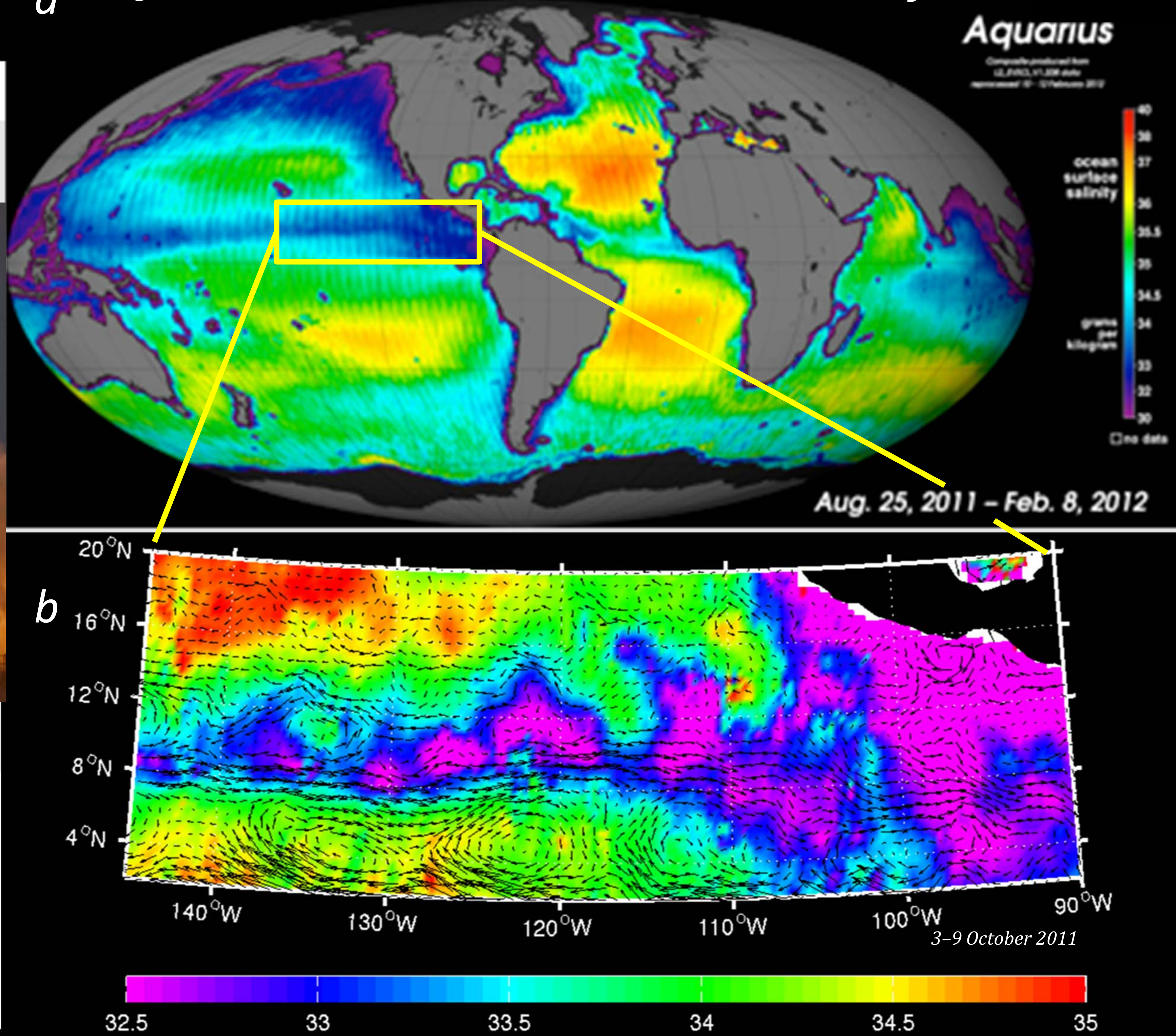
Multi-Channel (10-183 GHz) GPM Microwave Imager (GMI):

- *Higher spatial resolution (IFOV: 6-26 km)*
- *Improved light rain & snow detection*
- *Improved signals of solid precipitation over land (especially over snow-covered surfaces)*
- *4-point calibration to serve as a radiometeric reference for constellation radiometers*

Combined Radar-Radiometer Retrieval

- *DPR & GMI together provide greater constraints on possible solutions to improve retrieval accuracy*
- *Observation-based a-priori cloud database for constellation radiometer retrievals*

AQUARIUS – Sea-Surface Salinity



Soil Moisture – Active/Passive (SMAP; 2014)