# TRMM Status and Achievements

NASA Project Scientist: Dr. Scott Braun

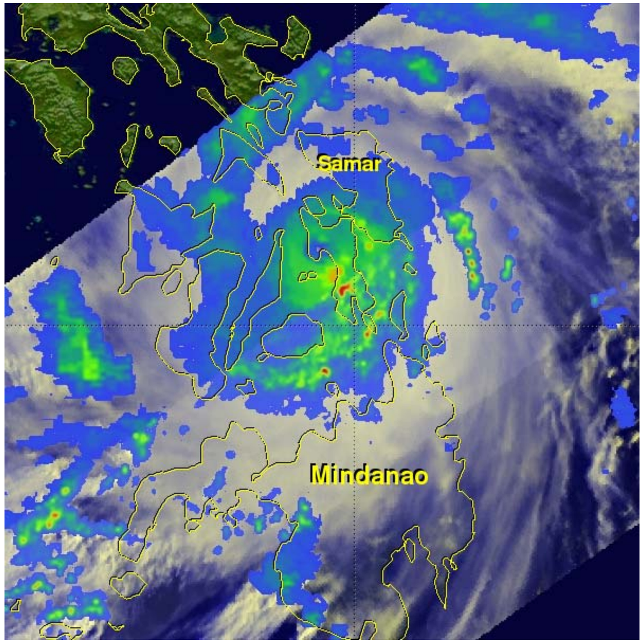
NASA Program Scientist: Dr. Ramesh Kakar

**Joint NASA/JAXA mission launched in Nov. 1997**

**Instrument Payload:**

- **TRMM Microwave Imager (TMI)**
  **10, 19, 37, 86 GHz, conical scanning**
- **Precipitation Radar (PR) [Japan]**
  **14 GHz, cross-track scanning**
- **Lightning Imaging Sensor (LIS)**
  **Staring optical array [MSFC]**
- **Visible IR Scanner (VIRS)**
  **5-channel, cross-track scanning**
- **Clouds and Earth's Radiant Energy System (CERES)**

*Supertyphoon Haiyan, November 8, 2013*



## Spacecraft and instrument status:

• All spacecraft systems in excellent shape for continuation (watching battery #2 for possible short in one cell)

• Precipitation Radar (PR) experienced anomaly in 2009, but since then has worked fine

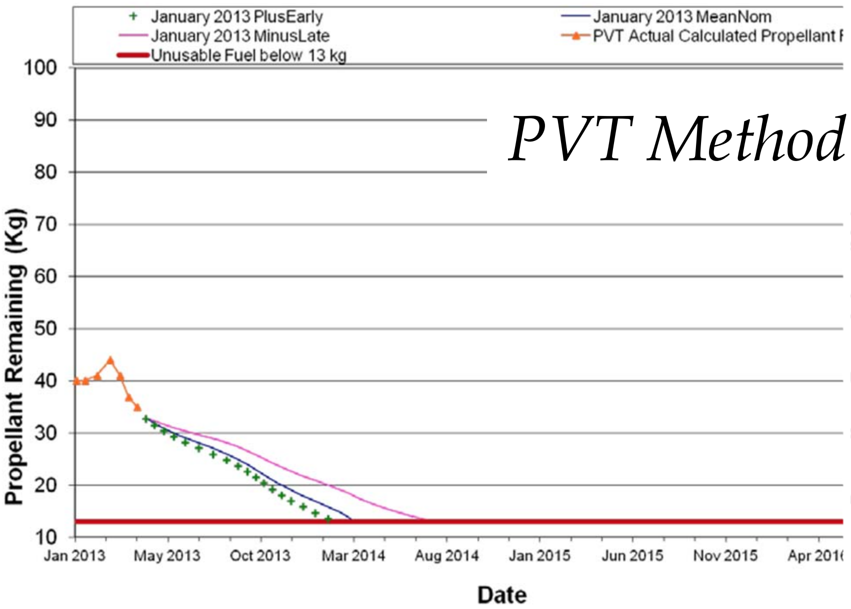
• TRMM Microwave Imager (TMI)—has equaled/ surpassed the SSM/I heritage of 10+ yr median lifetime;

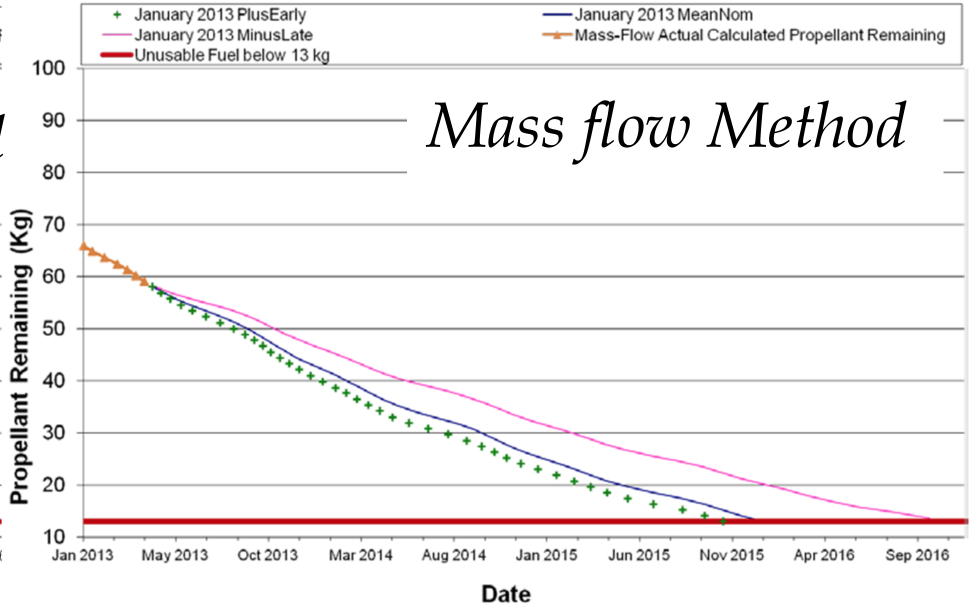
• Visible and IR Scanner (VIRS)—very minor response degradation;

• Lightning Imaging Sensor (LIS)—no moving parts, no component limiting life

• CERES failed after 8 months of operation

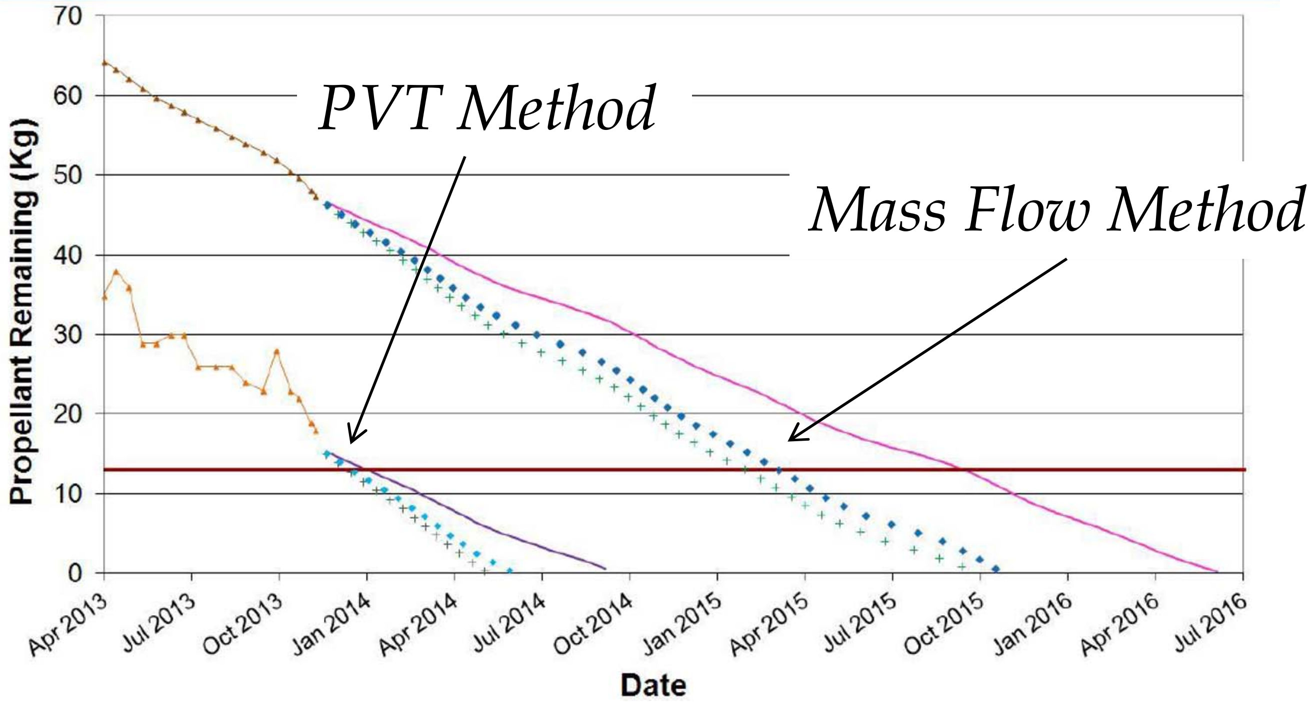
# TRMM Remaining Fuel – January 2013 Forecast



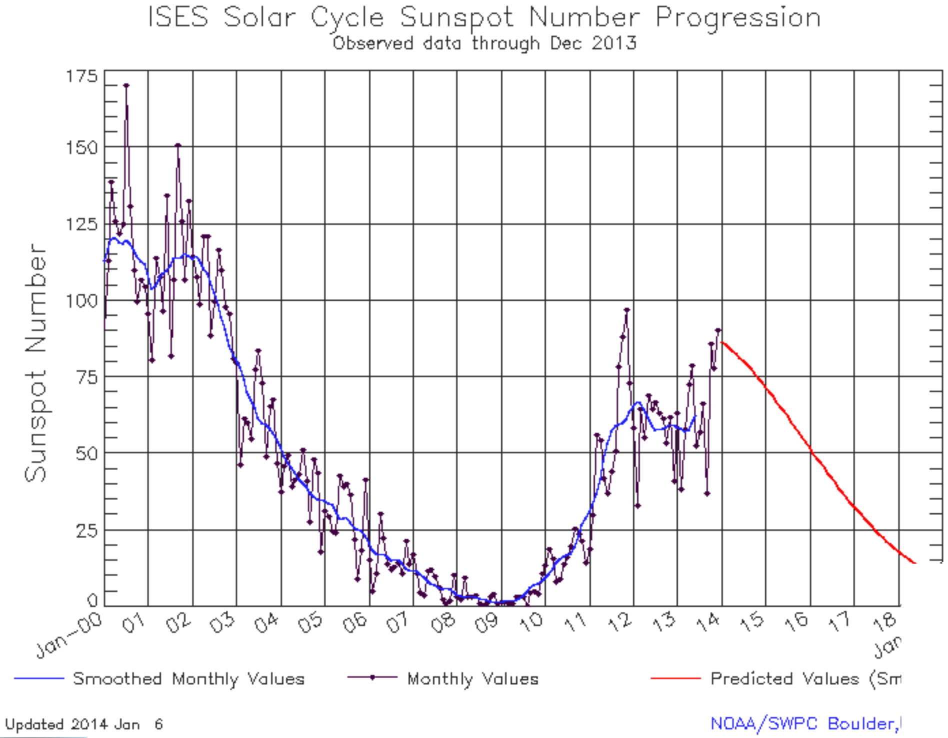

| Calibration method | Early | Nominal | Late |
|---|---|---|---|
| PVT | 2/2014 | 3/2014 | 8/2014 |
| Mass Flow | 11/2015 | 1/2016 | 11/2016 |

# TRMM Remaining Fuel – November 2013 Forecast



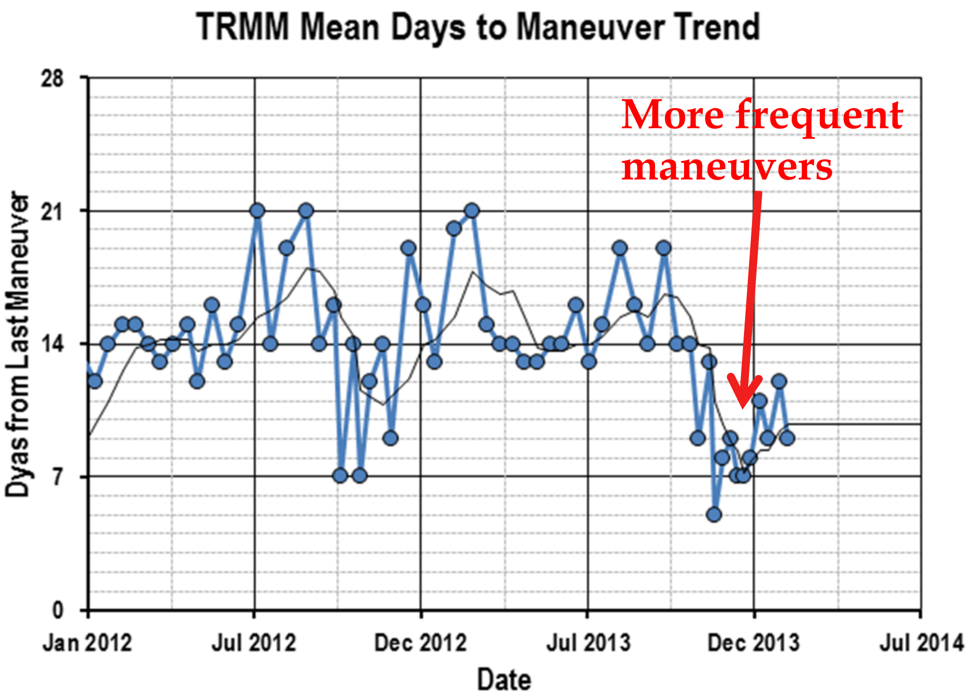

| Calibration method | Early | Nominal | Late |
|---|---|---|---|
| PVT | 12/2013<br>(-2 months) | 12/2013<br>(-3 months) | 12/2013<br>(-8 months) |
| Mass Flow | 2/2015<br>(-9 months) | 3/2015<br>(-10 months) | 9/2015<br>(-14 months) |

# *Greater Fuel Usage Caused by Increased Solar Fluxes*

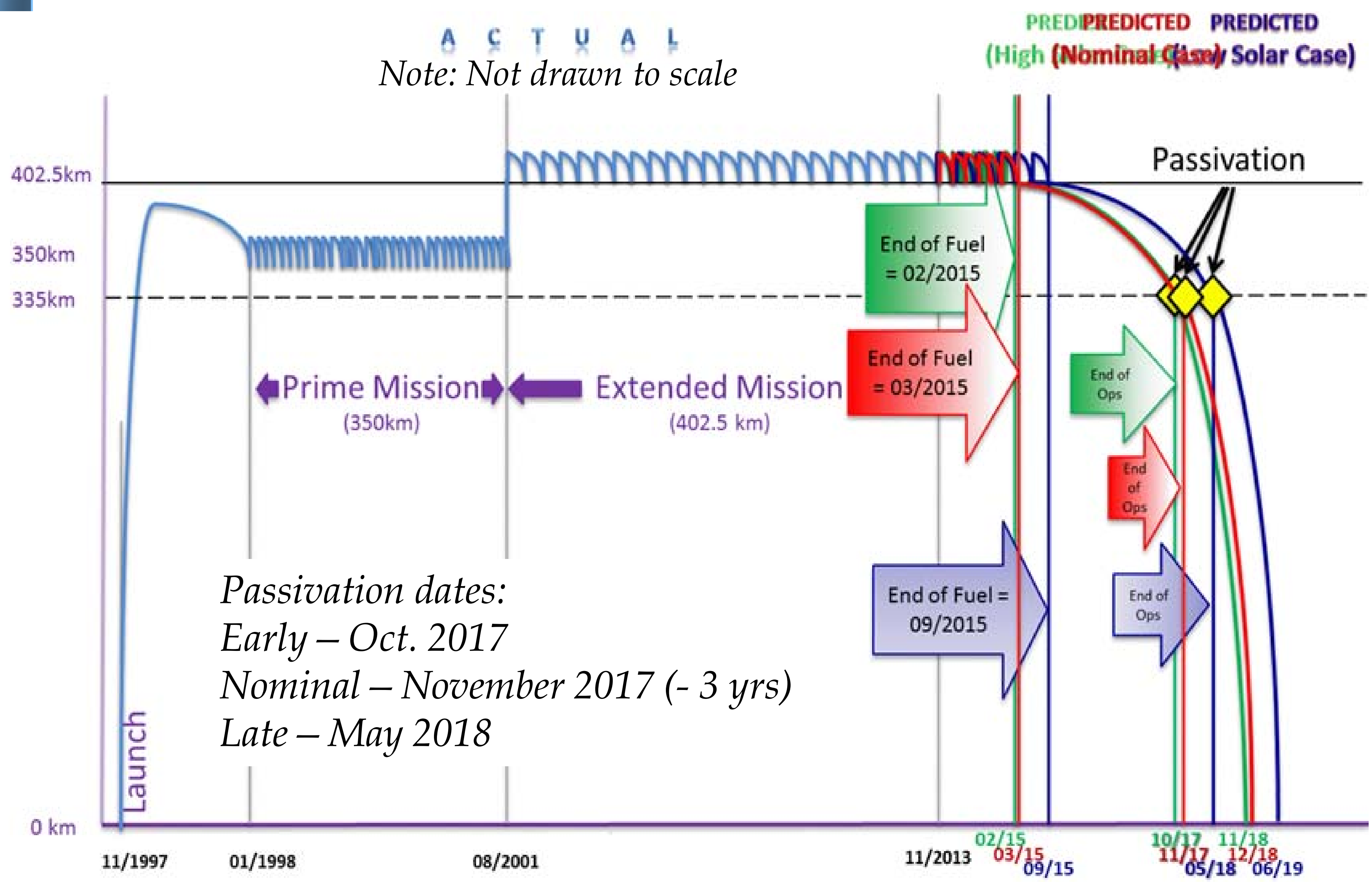



*Sunspot activity (left) recently increased sharply after almost two years of low activity*

*The time between TRMM orbit maneuvers (right) decreased significantly after September 2013 as sunspot activity increased*



# TRMM Notional Timeline



# 2013 Senior Review Results

- TRMM undergoes Senior Review process every 2 years
- Examines health status of missions, determines funding

| Mission | Science Scores | | | Summary Science Score | Utility Score | Technical Risk | Conclusion | |
|---|---|---|---|---|---|---|---|---|
| | Merit | Relevance | Product Maturity | | | | FY14-15 | FY16-17 |
| ACRIMSAT | 4.0 | 4.2 | 2.8 | 3.7 | Some | Medium-Low | Continue | Continue |
| Aqua | 5.0 | 5.0 | 4.7 | 4.9 | Very High | Medium | Continue | Continue |
| Aura | 5.0 | 5.0 | 4.9 | 5.0 | High | Medium-High | Continue | Continue |
| CALIPSO | 5.0 | 5.0 | 4.9 | 5.0 | High | Medium | Continue | Continue |
| CloudSat | 5.0 | 5.0 | 4.9 | 5.0 | High | Medium-High | Continue | Continue |
| EO-1 | 4.0 | 4.3 | 3.0 | 3.8 | Some | Medium-High | Continue | Terminate & Close out* |
| GRACE | 5.0 | 5.0 | 4.0 | 4.7 | High | High | Continue | Continue |
| Jason-1 | 5.0 | 5.0 | 5.0 | 5.0 | High | Medium-High | Continue | Continue & Reduce* |
| OSTM | 5.0 | 5.0 | 5.0 | 5.0 | High | Low | Continue | Continue |
| QuikSCAT | 5.0 | 5.0 | 5.0 | 5.0 | High | High | Continue | Continue |
| SORCE | 4.9 | 5.0 | 3.2 | 4.4 | High | High | Continue | Continue |
| Terra | 5.0 | 5.0 | 4.8 | 4.9 | Very High | Medium-Low | Continue | Continue |
| TRMM | 5.0 | 5.0 | 5.0 | 5.0 | Very High | High | Continue | Continue |

**User Community Ratings:**

- *NOAA National Weather Service — High*
- *NOAA National Ocean Service — Very High*
- *Federal Aviation Administration — Very High*
- *U.S. Dept. of Agriculture — Very High*
- *U.S. Geological Survey — High*
- *Environmental Protection Agency — High*
- *U.S. Navy — Very High*
- *U.S. Air Force — Very High*
- *National States Geographic Info. Council — Very High*
- *Private Sector/NGO's — High to Very High*

## Battery Issue:

• December 4, 2013, ~15:00 GMT, the TRMM Super NiCad Battery #2 temperature rapidly increased and the differential voltage diverged by approximately 1.3 volts. Within several hours, the battery voltages and temperatures returned to near nominal levels. The cause is likely due to a temporary short within one cell.

If a battery cell shorts, TRMM could enter Survival Mode due to low voltage.

## Debris Avoidance Maneuver (DAM):

• First ever DAM for TRMM occurred on Nov. 18 when a Conjunction Assessment and Risk Analysis suggested that a piece of an upper stage of a Delta 2 rocket would come within 300 m of TRMM with a probability of collision of 1:3448. Mission Ops performed upcoming drag make-up maneuver to raise TRMM altitude and avoid debris.

• Close monitoring of CubeSats released into orbit from Space Station on Nov. 19-20. Continued monitoring needed as orbits decay and CubeSats fall past TRMM (two in Dec. 2013, two in Jan. 2014).

## *Periods of data loss*:

- **Nov. 12, 2013, ~02:00 GMT, the TRMM spacecraft was reconfigured into a minimal 'safe' communications mode following the expiration of the stored command load. The Flight Operation Team (FOT) had inadvertently not loaded the updated command load due to an operator error. All Instruments remained in their normal science mode and the spacecraft platform maintained its science pointing. Resulted in a ~12 hour data loss.**

- **Nov. 12, 2013, ~20:00 GMT, unrecoverable data loss due to inaccurate Extended Precision Vector. Resulted in the loss of ~3.25 – 3.75 h of data.**

- **Nov. 19, 2013, ~09:00-16:00 GMT, sporadic unrecoverable data loss due to inaccurate acquisition vectors following Debris Avoidance Maneuver. Resulted in the loss of ~3.25 -4 h of data.**

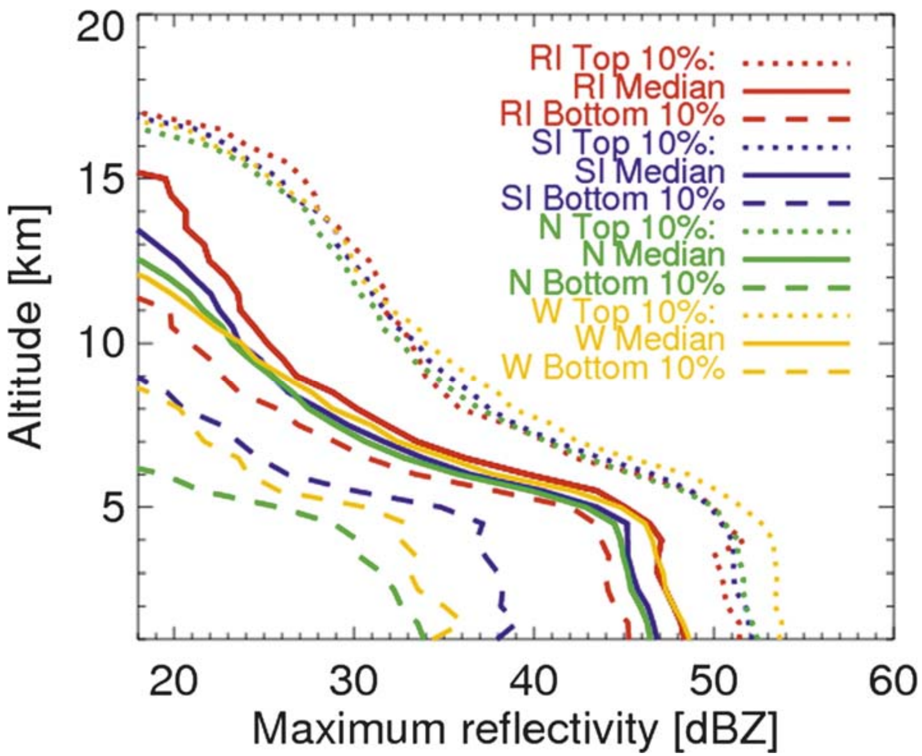
**Necessary Conditions for Tropical Cyclone Rapid Intensification as Derived from 11 Years of TRMM Data**

*Key Findings:*

- *Rapidly Intensifying (RI) storms always have in the inner core a*
  - *larger raining area*
  - *larger total volumetric rainfall*
  - *larger area with cold 85 GHz PCT*
  - *higher median echo heights*

- *RI storms have less lightning in the inner core, more in the outer bands*

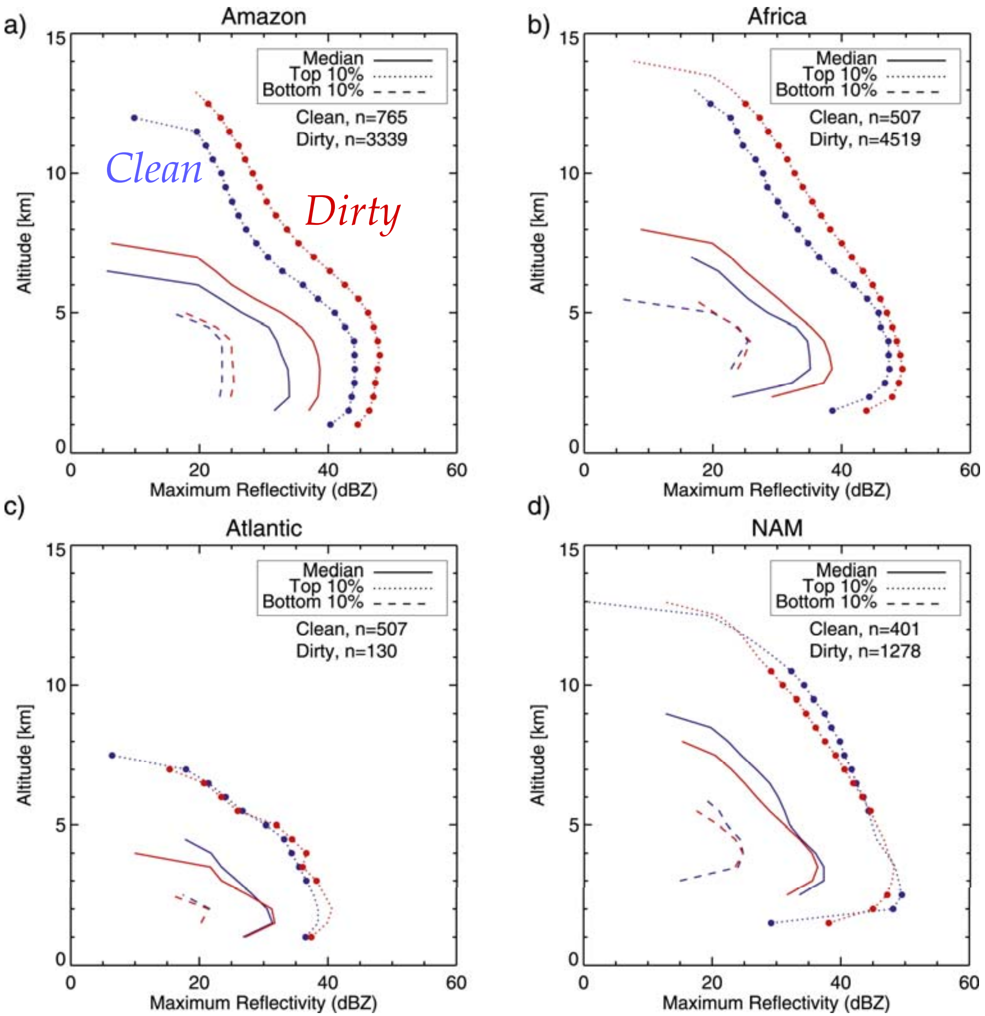
- *Weakening storms have more lightning in the inner core, less in the outer bands*




Bottom 10th percentile (dashed lines), median (solid lines), and 90th percentile (dotted lines) of vertical profiles of maximum radar reflectivity in the inner core of TCs in different intensity change stages.

## An Investigation of the Aerosol Indirect Effect on Convective Intensity Using Satellite Observations

- *Uses TRMM, CloudSat, Aqua/MODIS, and ECMWF analyses*
- TRMM PFs in the African/ Amazon regions are more intense, with more lightning under dirty conditions
- PFs in the SW U.S. are more intense under clean conditions
- Little difference in the Atl. region
- Differences in the mean thermodyn. profiles for PFs in clean and dirty environments could explain these differences in convective intensity.




Profiles of max. dBZ at each level for clean (blue) and dirty (red) RPFs. Dots on the top 10% profile indicate vertical levels at which the differences in the distributions of the clean and dirty dBZ values are statistically significant at the 99% level.

# Kidd, Dawkins, Huffman (J. Hydromet., 2013)

**Comparison of Precipitation Derived from the ECMWF Operational Forecast Model and Satellite Precipitation Datasets**

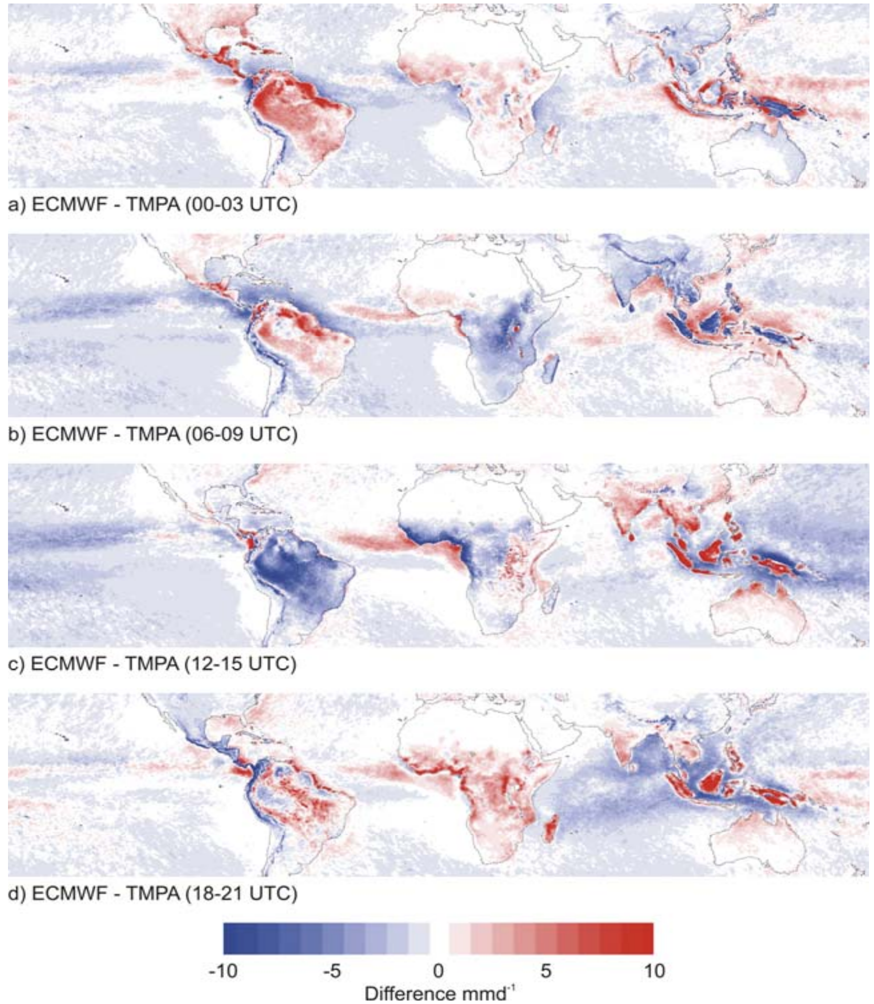
Before Nov. 2007, the EC model overestimated precip by up to 15%

This bias fell to about 4% after a new convective parameterization was implemented in 2007

The model diurnal cycle simulates rainfall too early compared to TRMM

The model was particularly poor over Indonesia

The model did not appear to simulate well mountain-slope breezes or the characteristics of MCSs

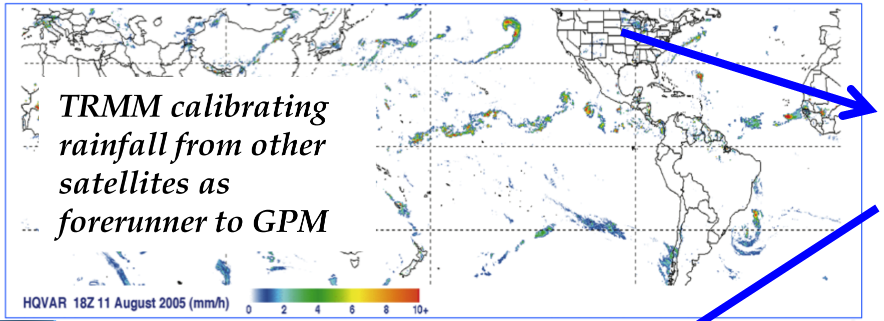



Diurnal differences between the ECMWF and TMPA precip. products for (top to bottom) 0000–0300, 0600–0900, 1200–1500, and 1800–2100 UTC during 2008–11. Blue (red) indicates ECMWF wetter (drier).

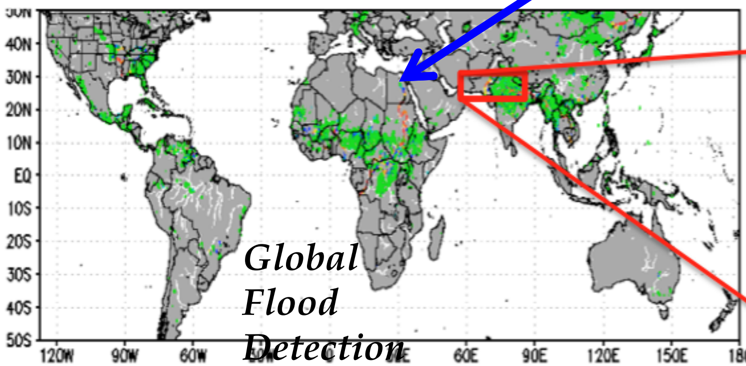
# Global Flood Monitoring System (GFMS)

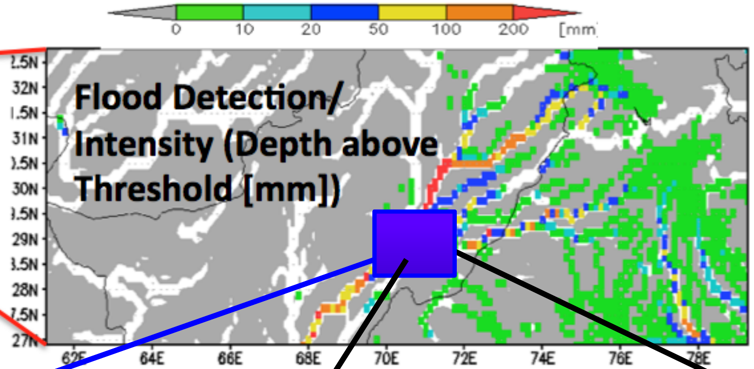
## *Global Real-time Flood Calculations Using Satellite Rainfall and Hydrological Model*

*http://flood.umd.edu/*

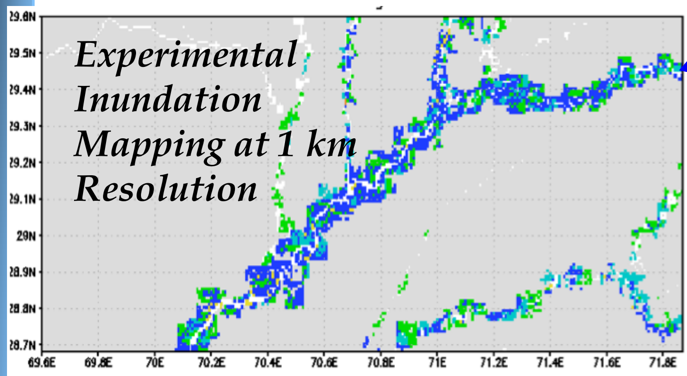


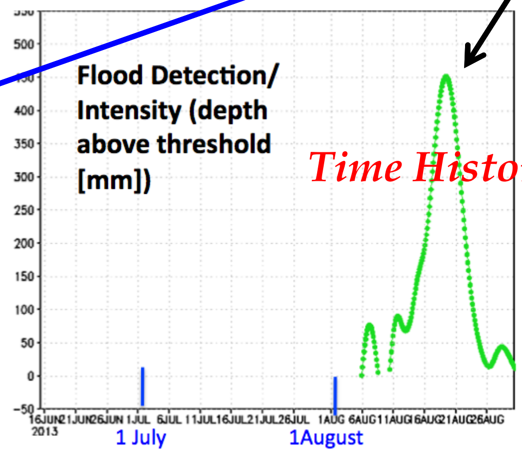

*TRMM/GPM rainfall into land surface and routing models for water depth and stream flow calculations compared to flood thresholds*




*Indus River basin Aug. 20 2013*




*Time Histories at a Point*