#### At the End of the TRMM Era: Precipitation Science Accomplishments and Applications For Societal Benefit

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NOVEMBER Average Rainfall mm/dd (3B43) 1998 to 2010



# TRMM PAYLOAD



Joint NASA/JAXA mission launched in <u>Nov. 1997</u> Instrument Payload:

- TRMM Microwave Imager (TMI)— 10, 19, 37, 86 GHz
- Precipitation Radar (PR) [Japan]— 14 GHz
- Lightning Imaging Sensor (LIS)— Staring optical array

10/28/2012 1725Z TRMM precipitation Radar 15dBZ Isosurface

prior to landfall

- Visible IR Scanner (VIRS)— 5-channels
- Clouds and Earth's Radiant Energy System (CERES)





# TRMM SCIENCE ACCOMPLISHMENTS



#### Key focus areas:

- Precipitation climatology and diurnal cycle
- Convective systems research: The University of Utah Precipitation Feature Database
- Floods: Science and applications
- Tropical cyclones: Science and applications
- Human impacts on precipitation



### TRMM RAINFALL CLIMATOLOGY



Benchmark 17+ year climatology

Unique monitoring of interannual rainfall variations related to ENSO

Comprehensive estimates of how rainfall is directly related to latent heat release (LHR)





### BENCHMARK FOR GLOBAL CLIMATE MODELS



Observed (TRMM) Dec-Feb Rainfall (mm)

TRMM estimates have become the standard for comparison to global reanalyses and climate models



From Kim and Alexander (2013)





### TRMM RAINFALL: DIURNAL CYCLE



Low inclination (35°), precessing orbit allows sampling of all local hours over several weeks

Quantification of diurnal cycle of precipitation tropics wide

Has also allowed focus on global, regional, and local scales



All Tropics over Land



Mesoscale Convective Systems

Features with significant ice scattering

Features without significant ice scattering

From Nesbitt and Zipser (2003)



# TRMM RAINFALL: DIURNAL CYCLE



#### Comparison with global forecast and climate models







### THE TRMM PRECIPITATION FEATURE DATABASE



• Continuously updated database of precip. features using PR, TMI, VIRS, and LIS

• Easy subsetting by location, time, feature size, dBZ, or other parameters

• Identifies occurrences of extremes, rain feature population statistics, vertical structure





# THE TRMM PRECIPITATION FEATURE DATABASE



#### TRMM PFD has yielded new insights into

- diurnal cycle of convective systems
- global distribution of convective extremes
- properties of electrified storms
- seasonal and regional distributions of warm rain
- tropical cyclone rainfall properties



FIG. 7b. As in Fig. 7a, but showing percentage of all strong events (highest four categories, all colors in Figs. 2-3) in each 2° × 2° box.



#### THE TRMM PRECIPITATION FEATURE DATABASE



The value of the TRMM dataset for climate research increases with every year of additional data

With 17+ yrs of data, analyses of regional seasonal variability are now becoming possible



Seasonal variation of radar precipitation feature characteristics in the Southeastern U. S. Courtesy of Chuntao Liu and Ed Zipser



# GLOBAL LIGHTNING CHARACTERISTICS





TRMM PR and LIS data used to find relationship between precipitation ice water content and lightning flash density

First global mapping of lightning with LIS including seasonal and diurnal cycles





### TRMM MULTI-SATELLITE PRECIPITATION ANALYSIS



3-hr window with passive micro-wave (gaps filled with Geo-IR) <u>calibrated</u> <u>by TRMM</u> (0.25 ° grid)

<u>Research product</u> uses TRMM radar information and monthly gauges





17 years+ ('98-'15) of 3-hr analysis available--produced at TRMM data system.

#### THE SCIENCE OF FLOOD EVENTS THE PAKISTAN FLOOD OF 2010







### UNIV. MD GLOBAL FLOOD MONITORING SYSTEM



GFMS uses TRMM 3B42RT data as input into a hydrological runoff and routing model

Output: • Flood detection and intensity • Antecedent rainfall • Streamflow and inundation



From Wu et al., (Water Resources Research, 2014)



# TROPICAL CYCLONES: APPLICATIONS



TRMM data used for tropical cyclone position, structure and intensity estimation

~600 TRMM tropical cyclone "fixes" per year

TRMM's orbit provides frequent observations in the 10-35° latitude band





TRMM <u>radar</u> (PR) crosssections of hurricanes were <u>available in real-</u> <u>time</u> for operational analysis from TRMM web site



#### TRMM TRACKS CHANGES IN RAIN STRUCTURE AND ACCUMULATION



#### TRMM provides detailed views of hurricanes (e.g., Hurricane Isabel in 2003).





The TRMM multi-satellite precipitation analysis helps map rainfall evolution in hurricanes.





#### TROPICAL CYCLONE SCIENCE ACCOMPLISHMENTS



- Rainfall climatologies in hurricanes
  - Radial distribution
  - Shear and motion induced asymmetries
  - Eyewall and rainband vertical structure and lightning
  - Precipitation feature database characteristics
- Data assimilation
- Evaluation of storm structures in mesoscale models
- Improved SST estimates in storm wakes



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## HOT TOWERS: IMPORTANT OR NOT?



Examined rapidly intensifying (RI), slowly intensifying (SI), neutral (N), and weakening (W) storms

In terms of measures of strong convection, RI storms not much different than others

RI storms tend to have larger areas of rainfall or convection







#### IMPACT OF HUMANS ON RAINFALL



#### **Impact of Cities on Rainfall**



**maximum (M. Shepherd)** Mean Annual PR Rainfall



#### **Pollution Impact on Rainfall Over Land**



Increase in Summer Rain over SE U.S. during the week (red curve)--Increase offshore on weekend (blue curve)—(Courtesy of T. Bell)



#### PRECIPITATION SUPPRESSION BY SMOKE



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





# SUMMARY OF TRMM ACCOMPLISHMENTS



- Space standard for measuring precipitation
- Improved climatology of tropical rainfall and variations
- Vertical hydrometeor/heating structure and diurnal signal
- Improved climate/weather modeling
- Impact of humans on rainfall
- Tropical cyclone structure/evolution
- Multi-satellite rainfall analyses using TRMM+other satellites
- Flood and agricultural applications
- Operational use of data by weather agencies.



#### TRMM citations 4500 4000 3500 2500 2500 2500 1500 1500 1000 500 0 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Web of Science publication and citation results based on title and keyword search for "TRMM". >2000 journal articles, >38,000 citations