Science Mission Directorate

Weather Focus Area

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for
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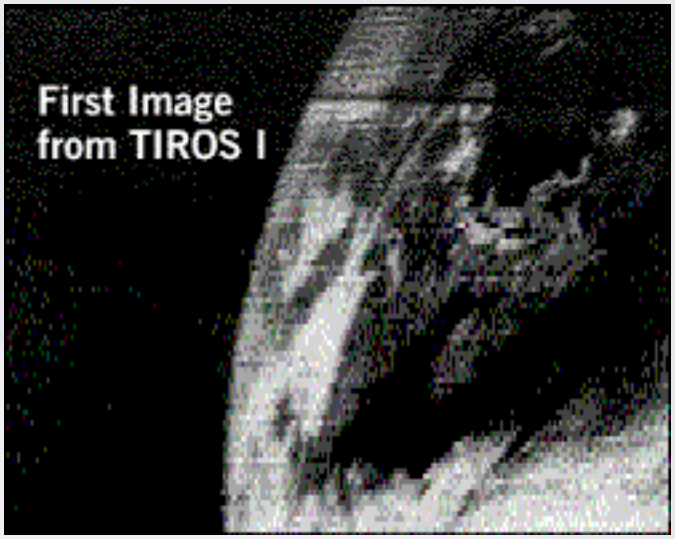
History & Background

- Since the early days of spaceage, NASA has been at the forefront of using the vantage point of space for observing how the weather systems develop

- The Space Act of 1958, as amended, assigns NASA the responsibility for expanding human knowledge of the Earth and of phenomena in the atmosphere and space and cooperating with interested U.S. agencies to avoid unnecessary duplication of effort

- The origin of almost all instruments that have ever flown on NOAA satellites can be traced back to the NASA programs



Objectives: To test experimental television techniques designed to develop a worldwide meteorological satellite information system. To test Sun angle and horizon sensor systems for spacecraft orientation.

Description: The spacecraft was 42 inches in diameter, 19 inches high and weighed 270 pounds. The craft was made of aluminum alloy and stainless steel which was then covered by 9200 solar cells. The solar cells served to charge the on-board batteries. Three pairs of solid-propellant spin rockets were mounted on the base plate.

TIROS-1

Launch Date
April 1, 1960
Operational Period
78 days
Launch Vehicle
Standard Thor-Able
Launch Site
Cape Canaveral, FL
Type
Weather Satellite

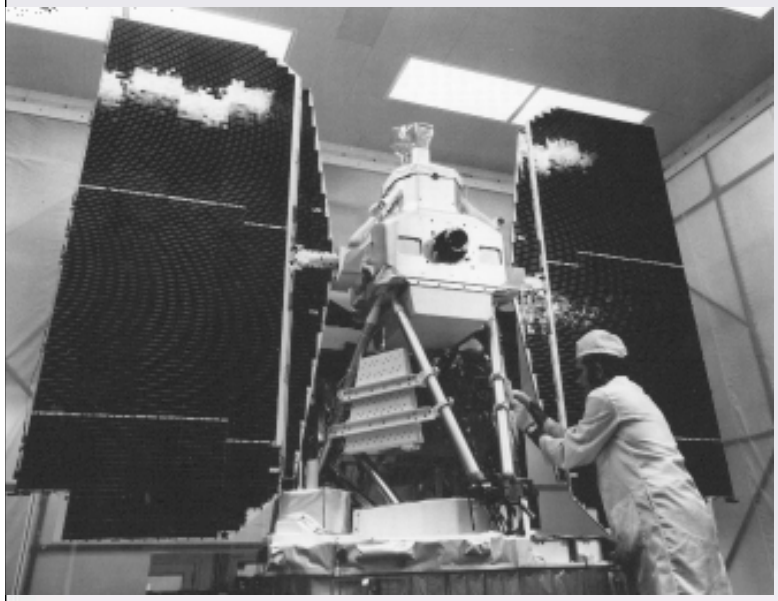


Photo: *Nimbus-5 undergoes final checks prior to shipment to the test range.*

Nimbus-5

Objectives: Continuation of research, development and testing of new meteorological sensors, systems and systems configurations to measure atmospheric temperature, water vapor and ozone. Those sensors which could be used in operational weather analysis and prediction were to be added to the NOAA operational weather satellite program.

Description: New experiments included an electrically scanning microwave radiometer, an infrared temperature profile radiometer, a microwave spectrometer, and a surface composition mapping radiometer. Improved versions of the chopper radiometer and the temperature, humidity and infrared radiometer were also flown.

Nimbus-5

Launch Date
December 10, 1972
Operational Period
Over 10 years until it was deactivated on March 29, 1983
Launch Vehicle
Delta 900
Launch Site
Vandenberg Air Force Base, CA
Type
Weather Satellite

Science Questions from the Research Strategy

Variability	Forcing	Response	Consequence	Prediction
Precipitation, evaporation & cycling of water changing?	Atmospheric constituents & solar radiation on climate?	Clouds & surface hydrological processes on climate?	Weather variation related to climate variation?	Weather forecasting improvement?
Global ocean circulation varying?	Changes in land cover & land use?	Ecosystem, land cover & biogeochemical responses?	Consequences of land cover & land use?	Improve predic-tion of climate variability & change?
Global ecosystems changing?	Motions of the Earth and Earth's interior?	Changes in global ocean circulation?	Coastal region impacts?	Ozone, climate & air quality impacts of atmospheric composition?
Stratospheric ozone changing?		Atmospheric trace constituents responses?	Regional air quality impacts?	Carbon cycle and ecosystem change?
Ice cover mass changing?		Sea level affected by Earth system change?		Change in water cycle dynamics?
Earth surface transformation?				Predict & mitigate natural hazards from Earth surface change?

Directly addressed by Weather Focus Area

What is weather prediction?

- Weather encompasses temperature, moisture, wind, clouds and precipitation, as well as severe storms
- Weather prediction is the determination of the future state of these variables as well as occurrence of severe storms
- Improvements in weather prediction have great social and economic value
- NASA contributes to improved prediction capability by providing
  - new and improved space-based observations
  - improved models and methods to assimilate the data

How Can Weather Forecast Duration and Reliability Be Improved By New Space-Based Observations, Assimilation, and Modeling?

Knowledge Base

Funded

Unfunded

= Field Campaign

Improvements require:

- Focused validation experiments
- New technology
- Impact assessments

T **Global tropospheric winds** → Forecast improvement

GEO : Lightning, ir & microwave sounding → Severe weather forecasts

T **Soil Moisture** → Improved weather, flood forecasts

Global Precipitation → Improved physical & dynamical processes

Global monitoring of water, energy, clouds, and air quality – Operational prototype mission → Significant forecast improvements

High-resolution global measurements of temperature, moisture, cloud properties, and aerosols (EOS instruments) → Better description of atmospheric dynamics, cloud distributions for radiation modeling, aerosol concentrations for air quality projection, and better imagery of snow/ice cover and severe weather phenomena like hurricanes and floods.

NASA/NOAA collaborative centers → Realistic and accelerated use by NOAA of new NASA knowledge, measurements, and data assimilation techniques.

Observations of tropical rainfall/energy release → Satellite-derived localized heating inputs leading to better physical understanding and modeling of precipitating systems.

Weather satellite sensor and technique development; used by NOAA → Steady, evolutionary improvement in weather prediction accuracy due to ongoing model refinement in operational agencies, finer-scale model resolution, improved use of probabilistic and statistical forecasting aided by multiple-component ensemble initializations, and incorporation of radar and aircraft-measurements

Systematic measurements of atmosphere, ocean, and land surface parameters

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

By 2015:

Weather and severe storm forecasting improvements:

- **Hurricane landfall accuracy improved for evacuation decisions;**
- **Winter storm hazards predicted for appropriate mitigation;**
- **Improved regional nowcasting of severe weather to enable life-saving actions, reducing false alarms;**
- **Quantitative precipitation forecasts accurate for economic decisions**

Key Roadmap Elements

- Modeling and Computing: Increased computing speed and advanced numerical models are required to complement increased resolution and accuracy of new observations
- Wind Lidar: Simulation experiments show that tropospheric wind profiles would provide a significant improvement to general and severe weather forecast accuracy
- Precipitation and Clouds: These observations are required to mitigate deficiencies in model physics and high synergy with wind measurements

Key Roadmap Elements (contd.)

- Geosynchronous Observations (especially microwave): Advanced imaging and sounding is required to complement advanced polar orbit observations with time resolution necessary to fully observe/understand weather scale processes

- Active Sounding (T, q, clouds): Next sounding breakthrough will be fine vertical resolution for boundary layer/ near surface information, accurate definitions of fronts and tropopause, and determination of cloud layers in order to interface with finer-scale models

Key Linkages

- Measurement of temperature, moisture (precipitation, clouds, soil moisture) and wind fields with enhanced temporal and spatial resolution is useful to the objectives of other focus areas (e.g. Climate, Water and Energy Cycle)
- Goals are jointly worked with other agencies via USWRP and other interagency activities
  - NOAA/NASA/NAVY/Air Force Joint Center for Satellite Data Assimilation
  - Short-term Prediction Research and Transition (SPoRT) - a NASA-NOAA-University collaboration
- NASA strives to transition knowledge, data, techniques and models to operational weather agencies in U.S. (NOAA, DoD) and across the world (through WMO)
- Solar System Mission within SMD

National Weather Forecast Improvement Goals

TODAY:

- Reliable 3-day forecasts of non-extreme weather
- 13-hour winter storm forecast
- 3-day severe local storm forecast with low-moderate confidence
- 16-minute thunderstorm advanced warning
- Tornado lead time 12 min
- Hurricane landfall tracking:
  +/- 240 km at 2-3 days
- Inconsistent hurricane intensity forecasts
- Air quality day-by-day

GOALS for 2015:

- Reliable 5-day forecasts of non-extreme weather
- 24-hour winter storm forecast
- 5-day severe local storm forecast with moderate confidence
- 30-minute thunderstorm advanced warning
- Tornado lead time 20 min
- Hurricane landfall tracking:
  +/- 160 km at 2-3 days
- Dependable hurricane intensity, precip forecasts
- Air quality forecast at 2 days

Impact of AIRS on Global Forecast Skill

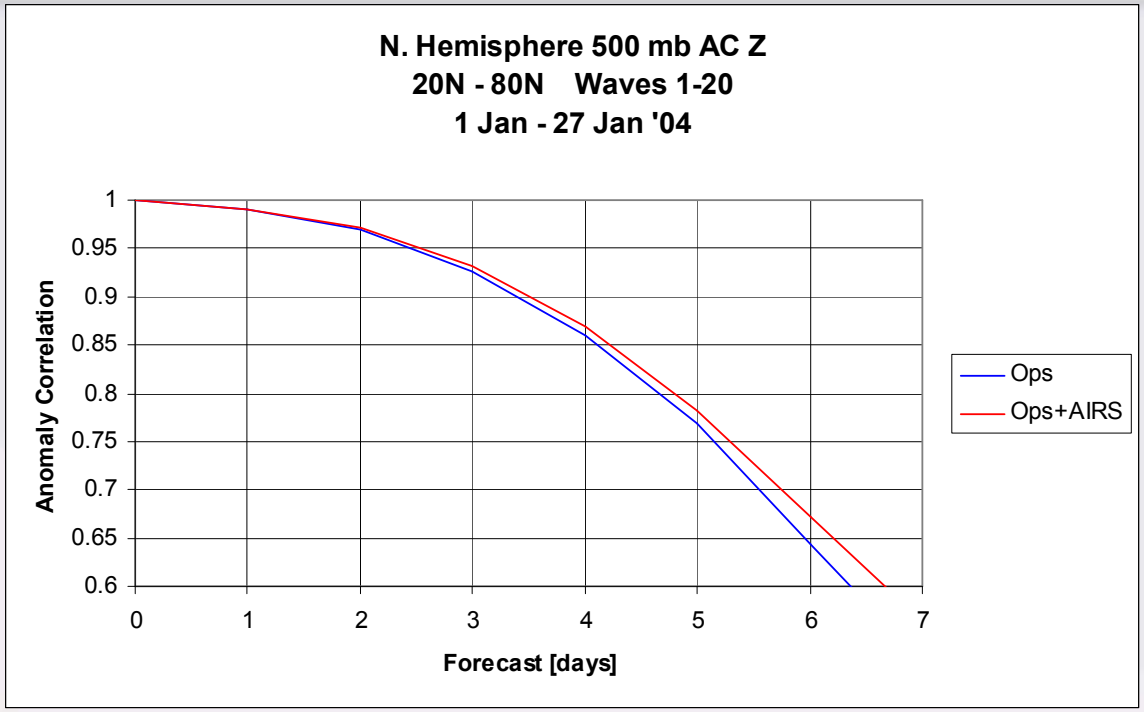
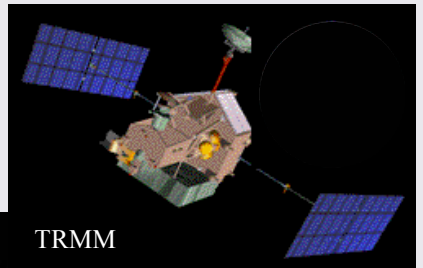


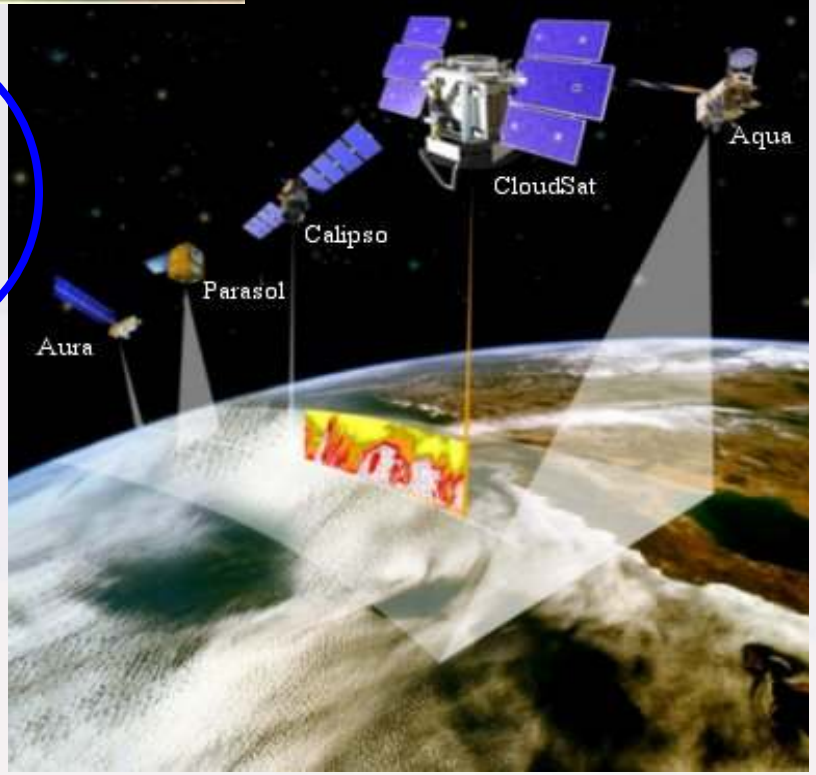
Figure: 500hPa Z Anomaly Correlations with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

"Experimental weather forecasts at the Joint Center for Satellite Data Assimilation using AIRS radiance data indicate significant improvements in global forecast skill compared to the operational system without AIRS data. The improvement in forecast skill at 6 days is equivalent to gaining an extension of forecast capability of several hours. While this may seem small, it is quite significant when compared to the rate of general forecast improvement over the last decade. A several hour increase in forecast range at 5 or 6 days normally takes several years to achieve at operational weather centers."

High Impact Weather: Hurricane Research

RESEARCH SYNERGY





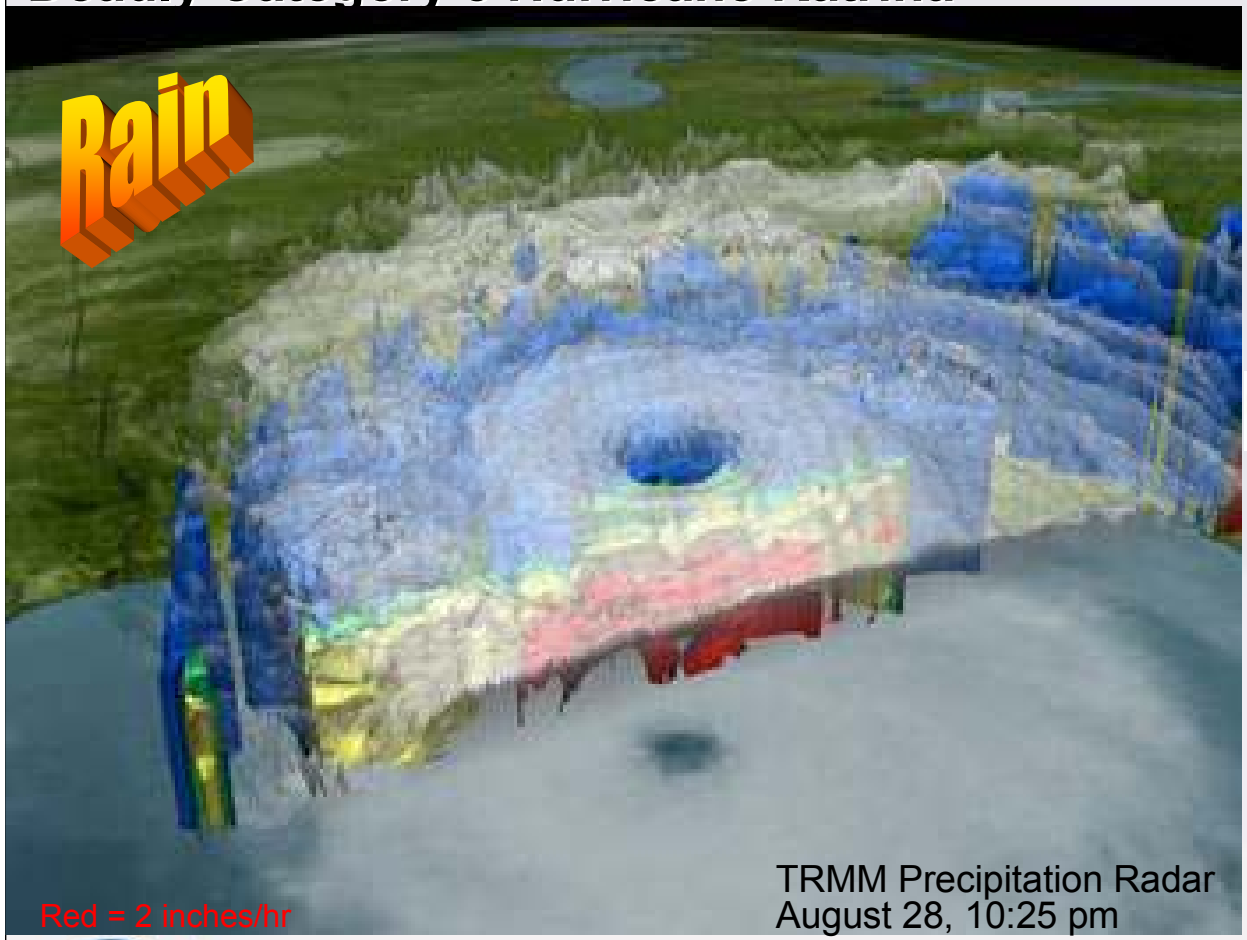
Models

Aircraft

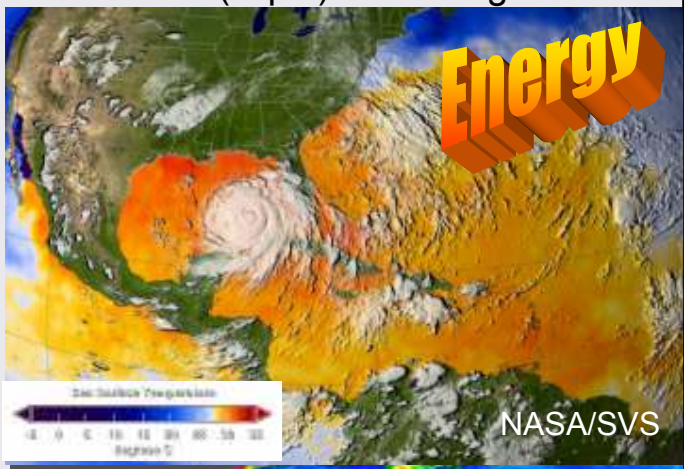
Satellite

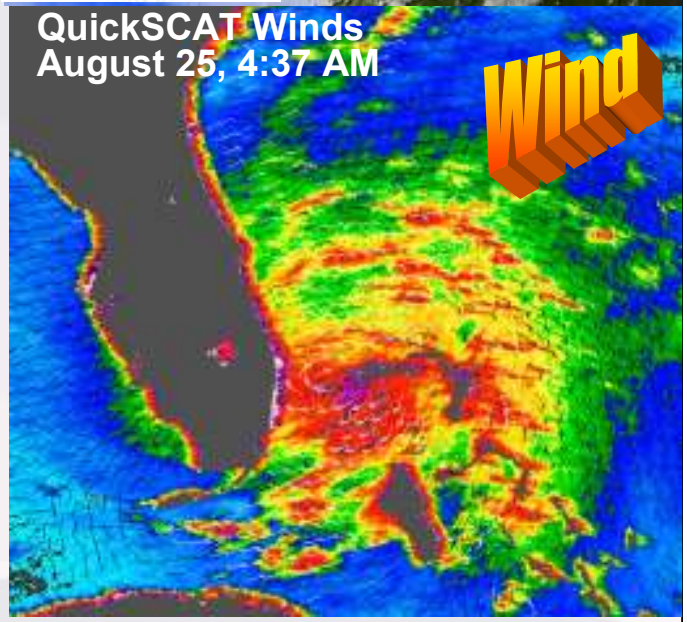
NASA Remote Sensors Image the Hurricane "Heat Engine"

NASA Earth Science Spacecraft Observe the Birth and Intensification of Deadly Category 5 Hurricane Katrina

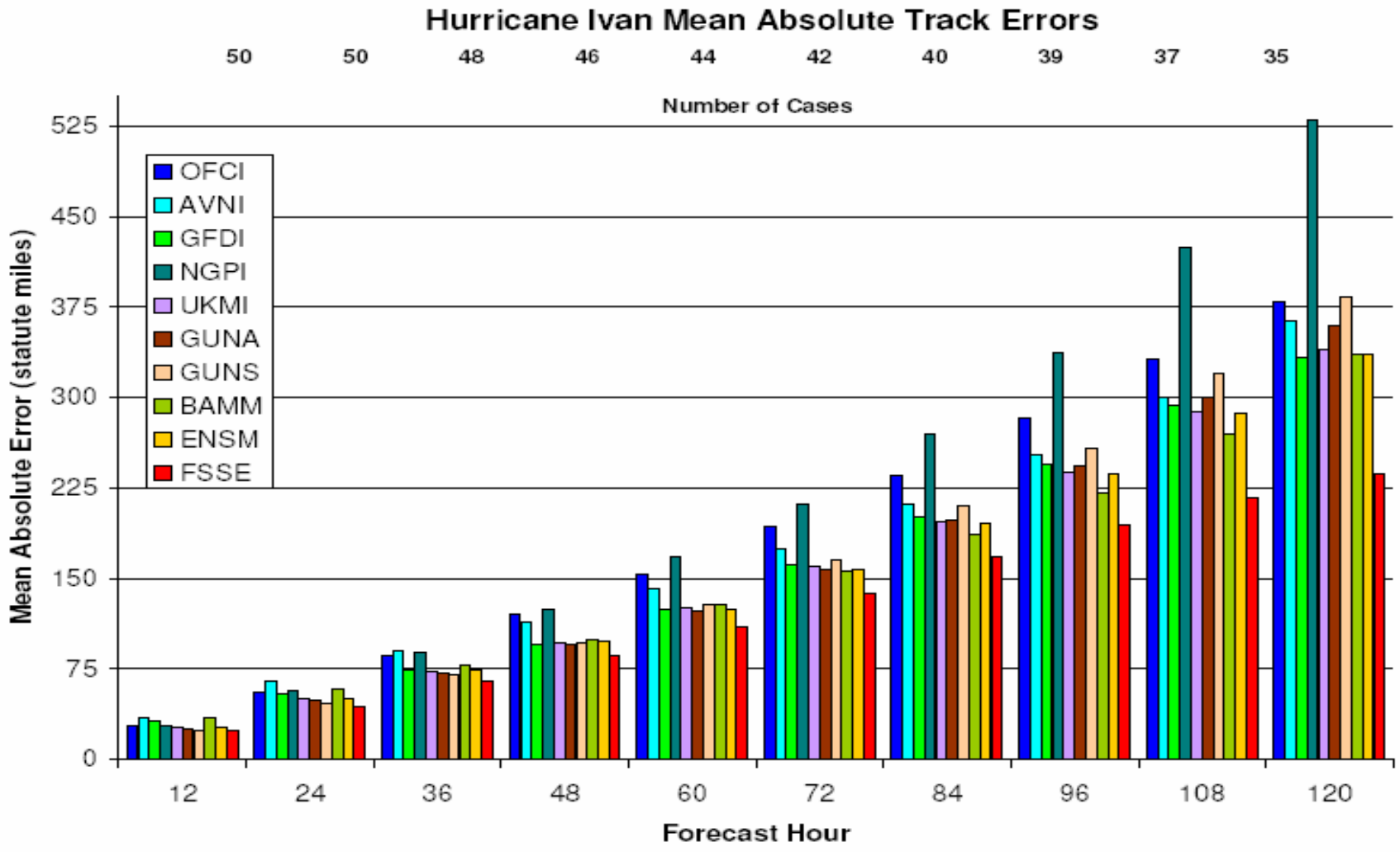


AMSR-E (Aqua) SSTs August 15-27





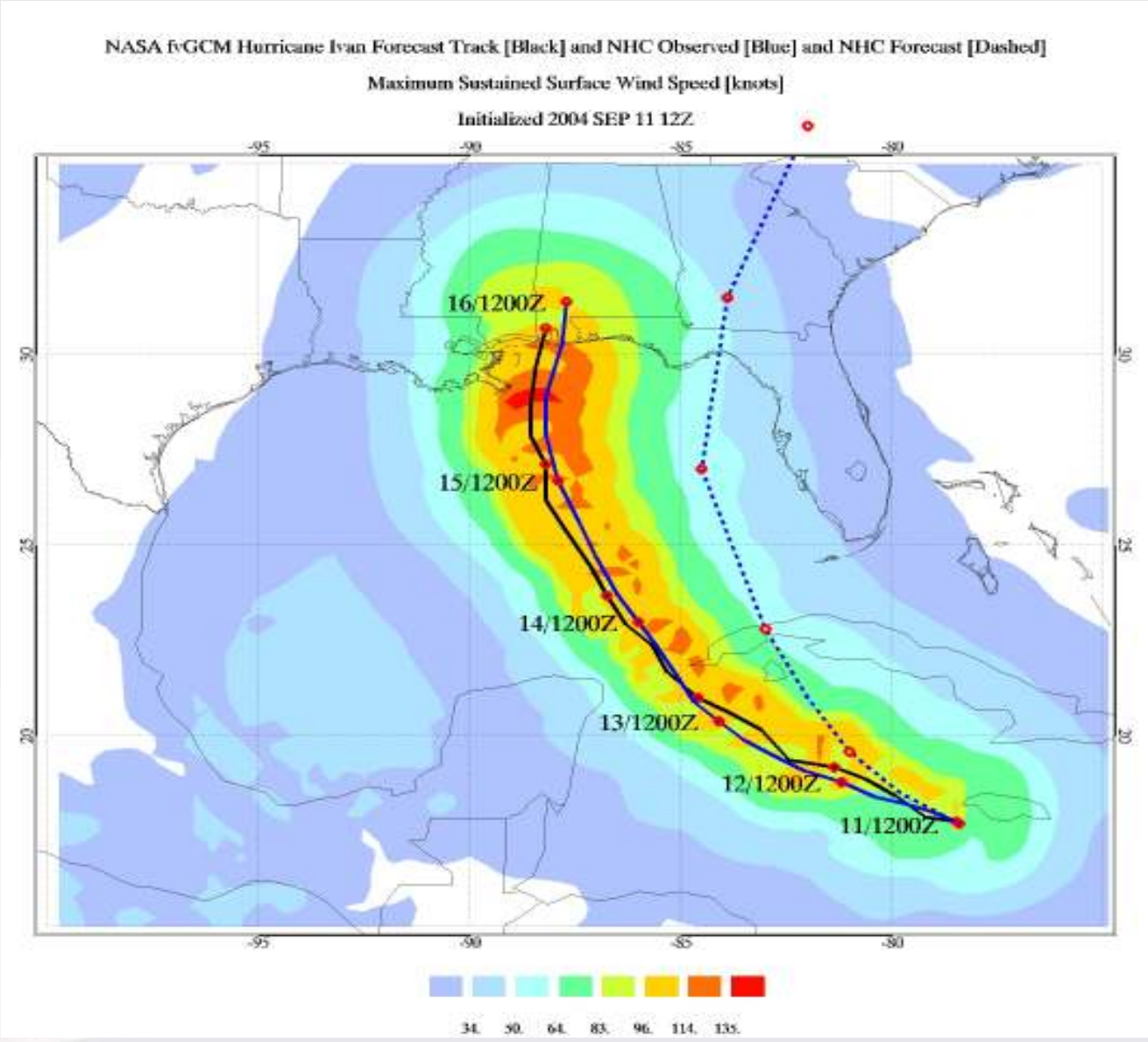
QuickSCAT Science Team, JPL



FSU Super Ensemble model is enhanced with data from TRMM, QuickSCAT and CAMEX

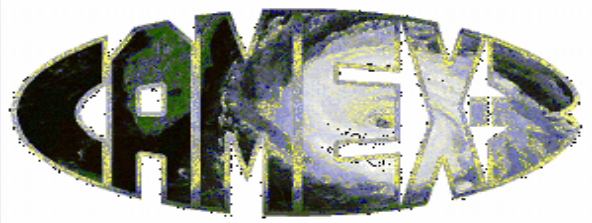
Hurricane Ivan
fvGCM Track and Intensity Forecast

- NASA fvGCM 5-day forecast shows vast improvement in accuracy of track, landfall, and intensity over operational prediction in this case
- Uses data from operational satellites, SSM-I, TRMM and QuickSCAT



NASA's Heritage of Hurricane Research Field Programs

- Joint partnership with NOAA HRD
- Blending of *in situ* and satellite data sets
- Improved parameterization of models
- Data assimilation to improve models
- Technology testbed (i.e. ER-2 dropsonde, Aerosonde)



CAMEX-3

- Inner core dynamics
- Synoptic flow environment
- Landfalling intensity change
- Genesis environment

CAMEX-4

- Rapid intensification
- Storm movement
- Structure and dynamics
- Scale interactions
- Remote sensing techniques

TCSP

- Genesis in EPAC, GOMEX, ATL
- Rapid intensification
- Easterly wave dynamics
- Satellite cal/val

Tropical Cloud Systems & Processes (TCSP) - 2005

- Tropical cyclogenesis
- Mesoscale Convective Systems
- Tropical Tropopause Layer dynamics
- Anvil cloud moisture and radiative feedbacks
- Adaptive/targeted observations for improved tropical cyclone prediction

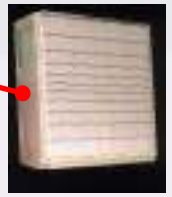
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

NASA ER-2:
Virtual Satellite

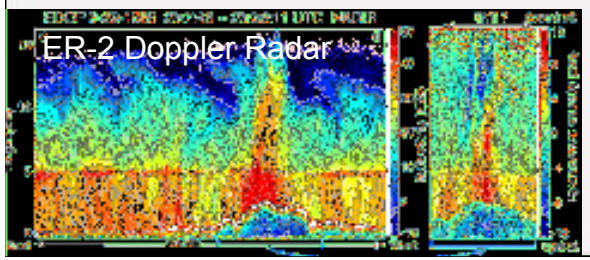
MODIS

Lightning
Imaging Sensor

TRMM
Microwave
Imager

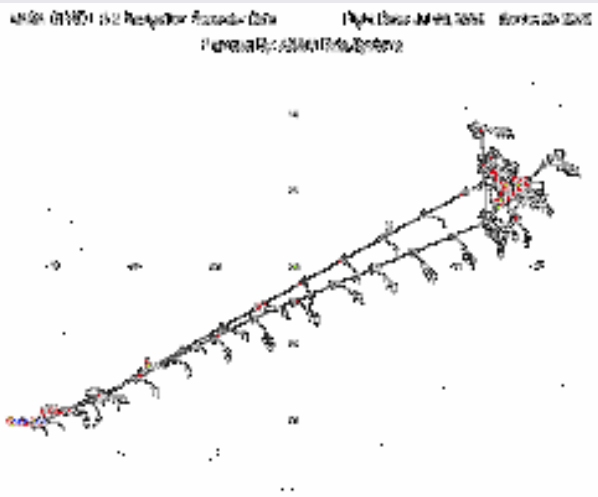


Precipitation
Radar

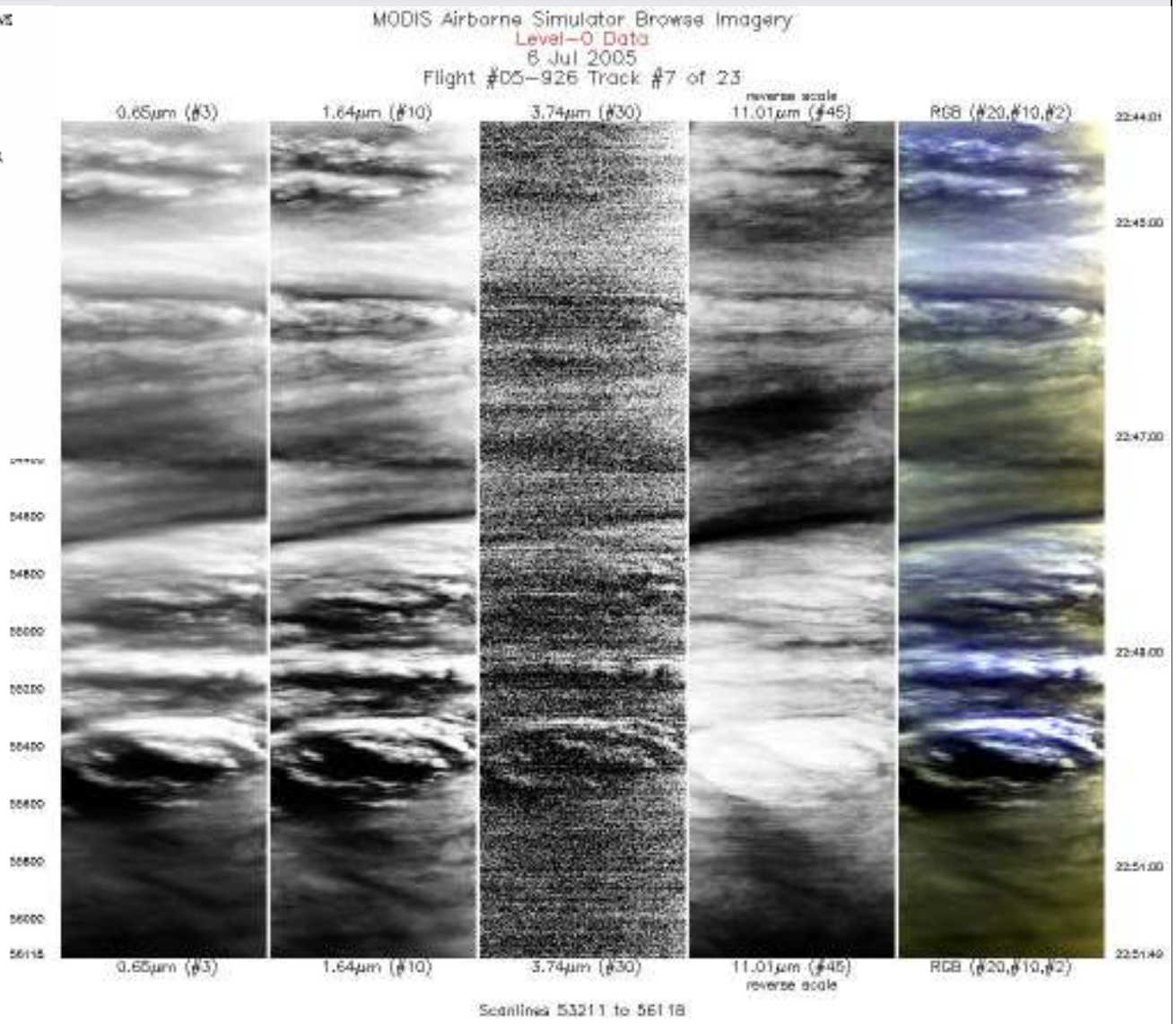


AMSR-E

MAS: MODIS Airborne Simulator

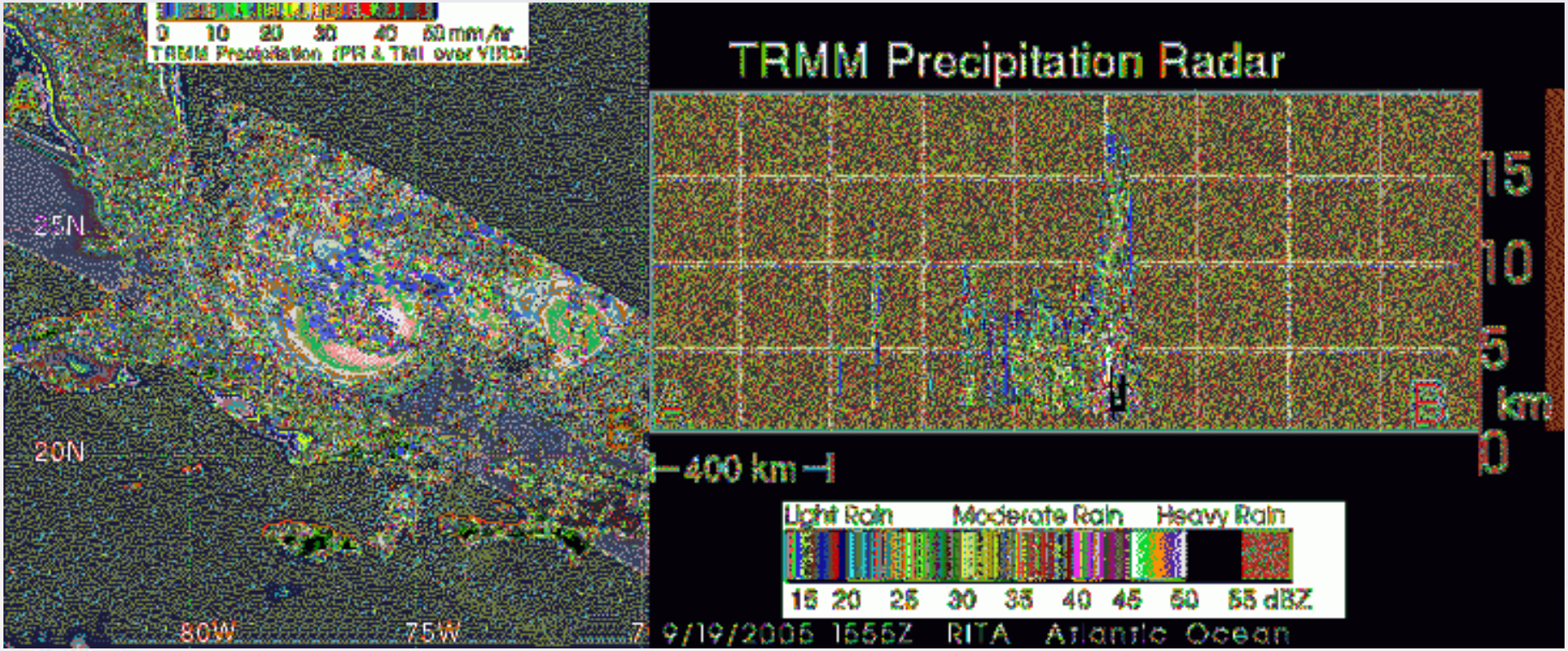


tcsp.msfc.nasa.gov



TRMM: Near-Real Time Vertical Rain Structure in Tropical Cyclones

- TRMM (ongoing now for 7+ years) provides highly detailed horizontal and vertical structure of rainfall inside tropical cyclones
- Used operationally to identify eye location, especially when obscured by cloud
- Early detection of tall cloud towers which are associated w/ rapid intensification

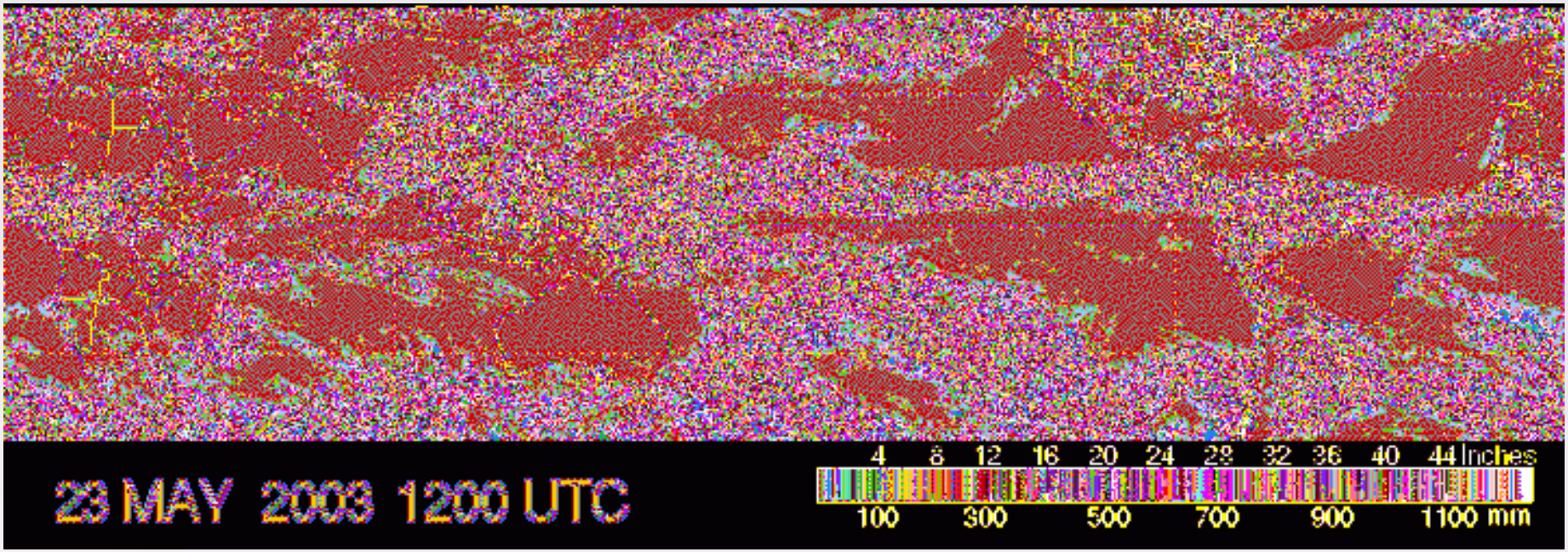


trmm.gsfc.nasa.gov

NAMMA-06: Tropical Cyclogenesis in The Eastern Atlantic

- Leverages off AMMA SOP-3 (Aug-Sept, 2006) in Cape Verde
- NASA-NOAA joint missions b/t DC-8 and G-IV
- DC-8 payload critical mass: Active radar, passive microwave, lidar, dropsondes, microphysics, profiler, *in situ* met obs
- Impact of African dusts on cyclogenesis

TRMM-Based Multi-satellite Precipitation Analysis



- Timely, accurate, fine-scale rainfall estimate for a variety of global applications
- Near-real time, 3-hourly rainfall estimates at 0.25º grid spacing from 50° N to 50° S
- TRMM is the calibrator of a combined microwave/IR sensor web (SSM/I, AMSR, AMSU)
- Automatic identification of potential flood regions on timescales of 1-, 3- and 7 days
- Utilized by NOAA NESDIS, CPC and international agencies i.e. UN and Australian BMRC
- The MPA sensor web is a precursor to the Global Precipitation Mission (GPM)

trmm.gsfc.nasa.gov

TRMM's Transition Into the GPM Era

Improving weather, climate, and hydrological forecasts through enhanced spatial and temporal measurement of precipitation.

Core Spacecraft

- *Dual Frequency Radar*
- *Multi-frequency Radiometer*
- *H-IIA Launch*
- *TRMM-like Spacecraft*
- *Non-Sun Synchronous Orbit*
- *~65° Inclination*
- *~400 km Altitude*
- *~5 km Horizontal Resolution*
- *250 m Vertical Resolution*
- *Discrimination of liquid and frozen precipitation*

Constellation Satellites

- *Multiple Satellites with Microwave Radiometers*
- *Sampling Sufficient to Resolve the Diurnal Cycle*
- *Sun-Synchronous Polar and Other Orbits*
- *~600-900 km Altitudes*

Developing international partnerships to understand global precipitation and its impact on humankind.

Summary

- New science instruments developed by NASA are precursors to the development of operational satellite instrumentation. Technology for new needed space-based observations can only be developed and flight-proven by NASA.
- Research by NASA scientists on how to use new space-based observations is essential element for demonstrating utility and leading to their operational use. Without this research, most satellite observations would not be used effectively.
- NASA observations and their use by operational agencies has and continues to save human lives and mitigate economic losses.
- Components of the NASA global cloud-resolving model being developed for weather and climate will be directly applicable to the atmospheres of other planets like MARS, and will provide a unique weather prediction capability that is required for the safety of astronauts and assets on these planets.