The Abdus Salam
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for Theoretical Physics

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2453-6

School on Modelling Tools and Capacity Building in Climate and Public Health

15 - 26 April 2013

Rainfall Estimation

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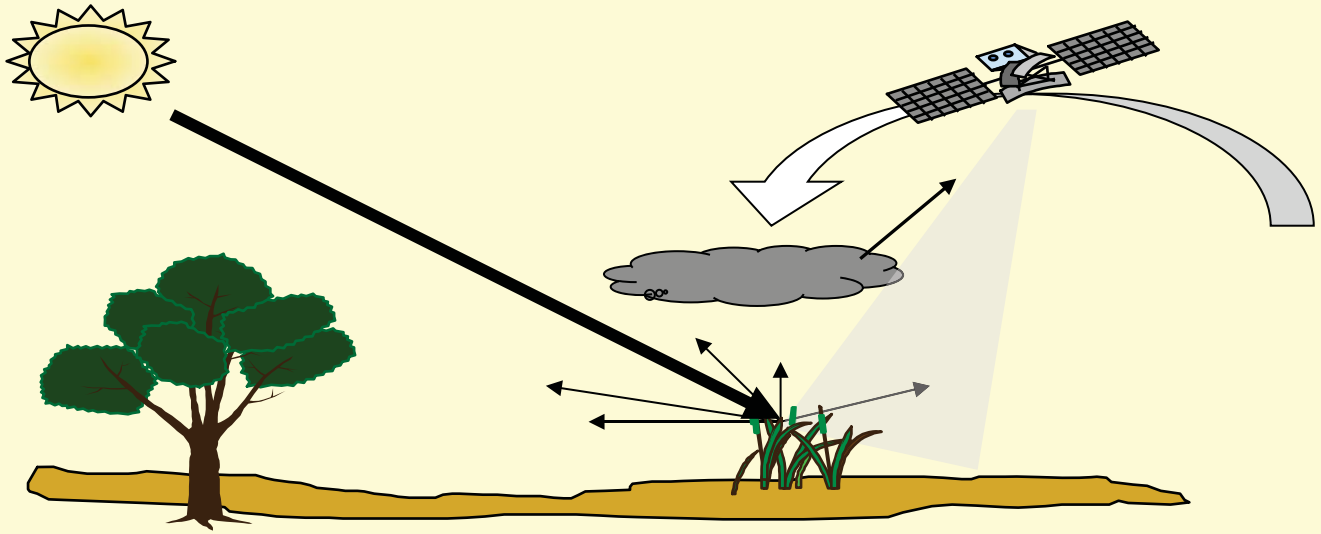
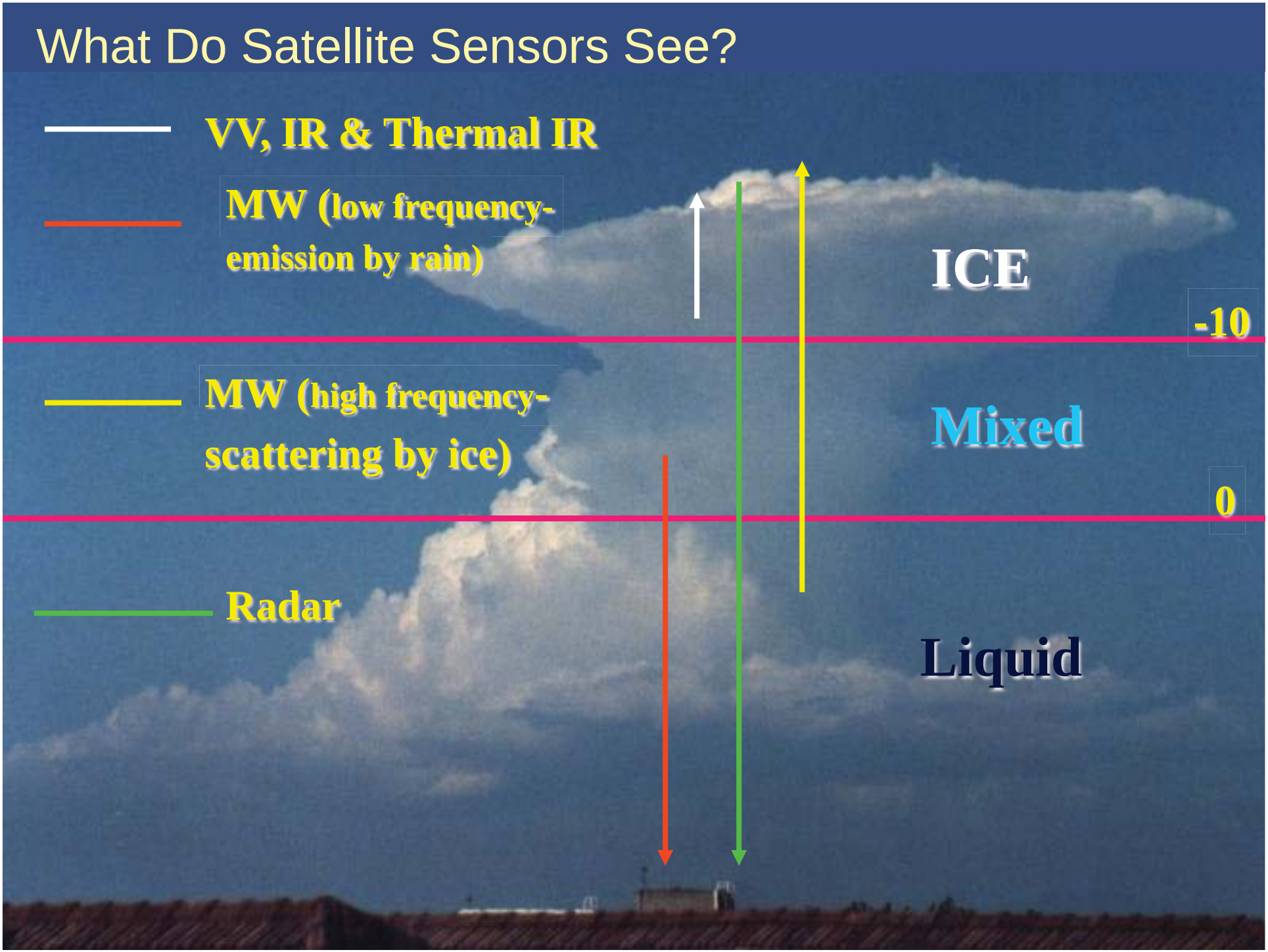
Rainfall Estimation



What is Satellite Rainfall Estimation?

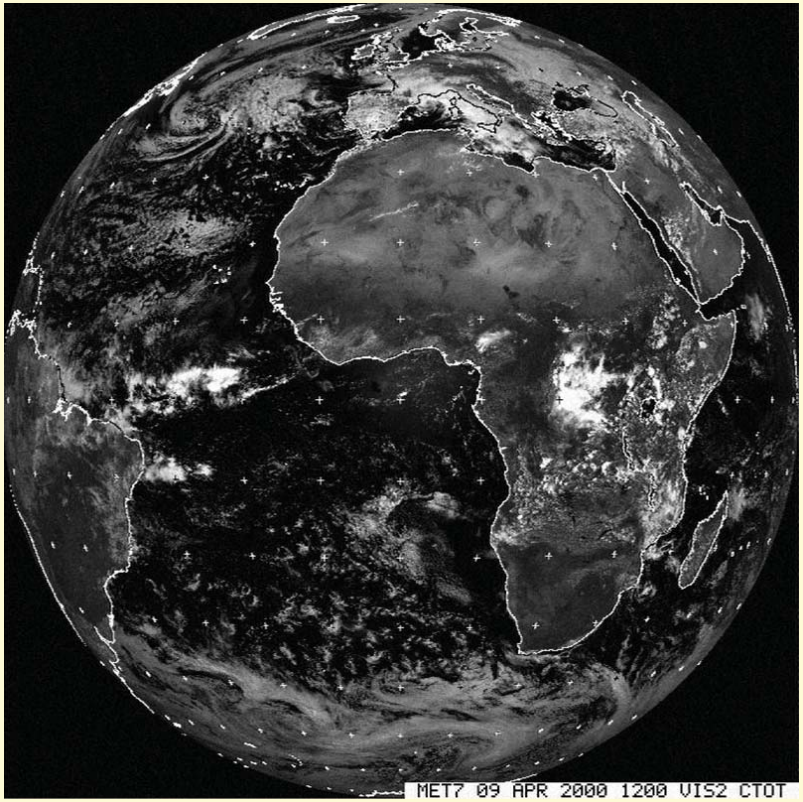
- There is no such thing as satellite rainfall measurement
- Satellite sensors just measure radiation emitted or reflected by hydrometeors and/or surface
- Satellite rainfall estimation techniques try to convert radiation measurements to precipitation information

What Do Satellite Sensors See?

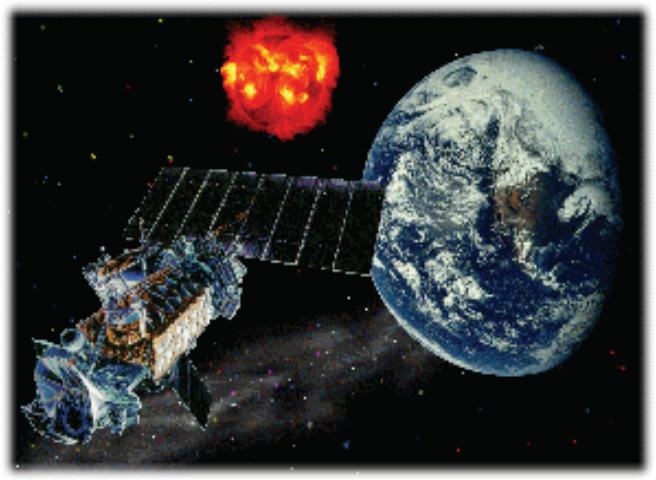


Geostationary Satellites

- Located at about 35,800 km above the equator
- Visible, NIR and Thermal Infrared
- Repeat coverage about 15 to 30 minutes
- Observes events and their evolution



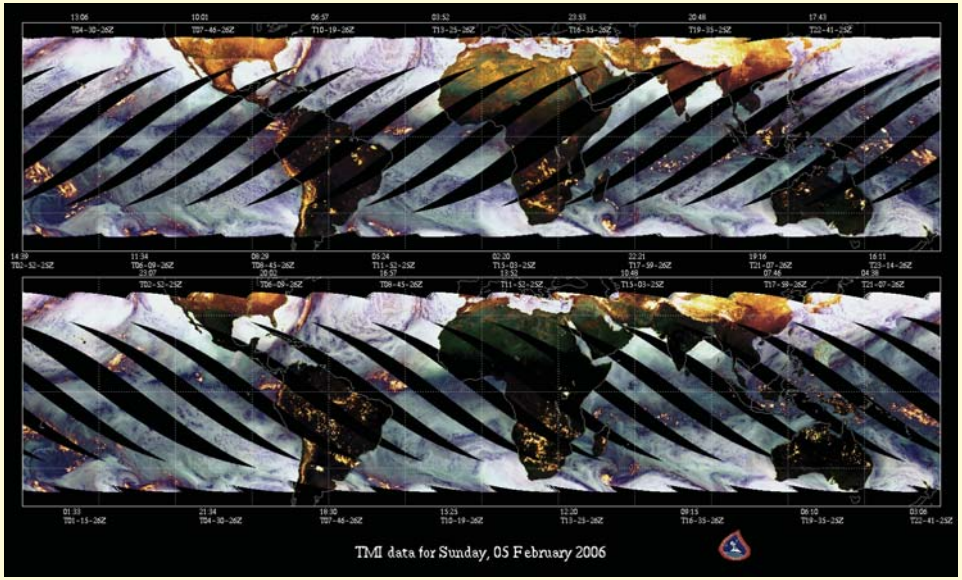
Polar-Orbiting Satellites Passive Microwave



Defense Meteorological Satellite Program (DMSP)

Special Sensor Microwave/Imager (SSM/I)

- Swath width: 1400-km
- Seven passive MW channels

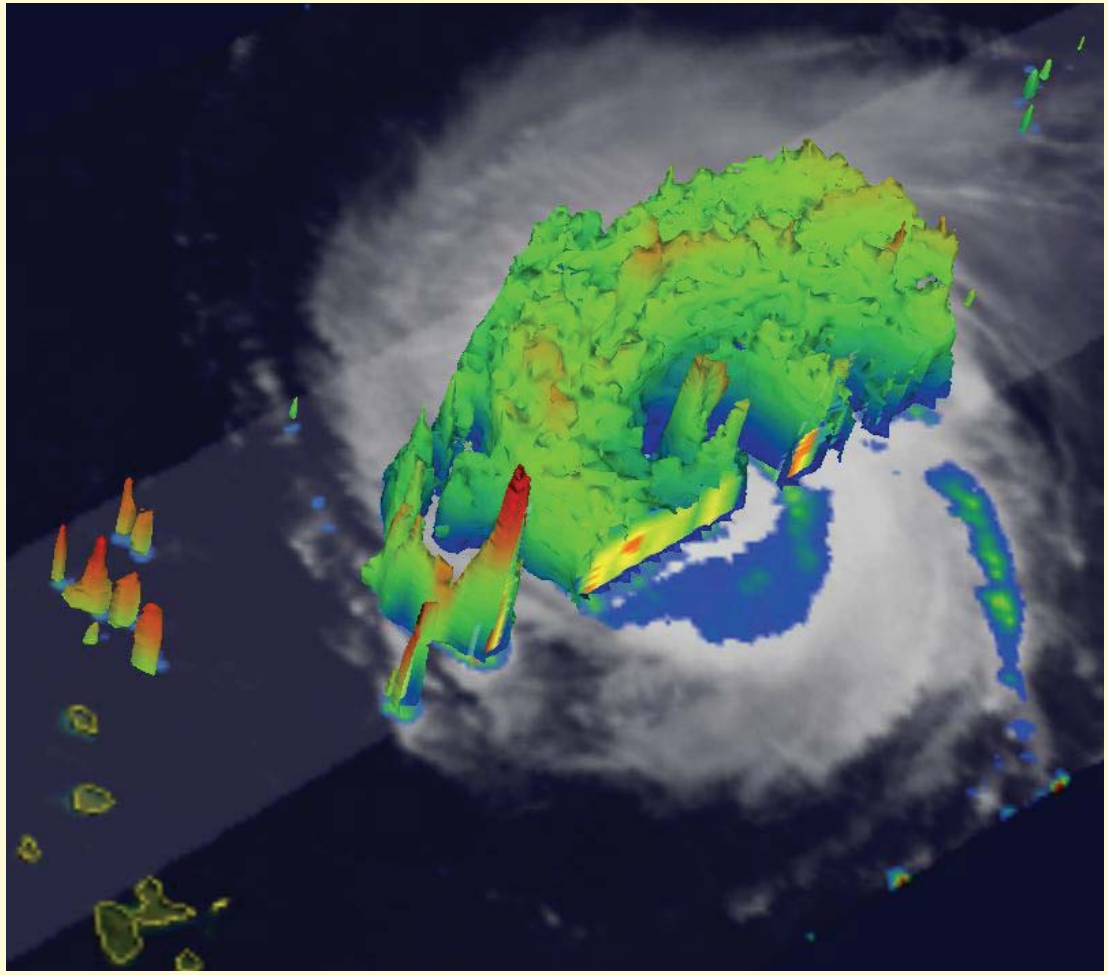


Radar and Passive Microwave on-board Satellites

Tropical Rainfall Measurement Mission (TRMM)

- **Precipitation radar (PR)**
  - **215 km Swath**
  - **250 m vertical resolution**
- **TMI**
  - **9-channel MW**
  - **760 km swath**
- **VV/IR**
- **Lightening detector**

TRMM product



Merging IR, Passive and Active Microwave

Rainfall Estimates

Combines the best features of both approaches:

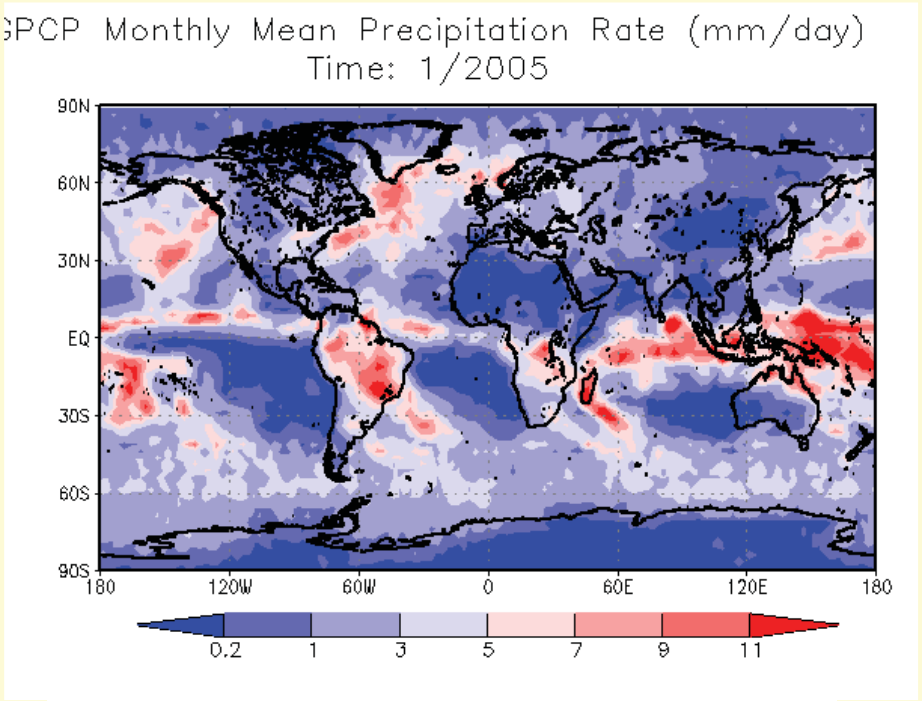
- Good *space/time resolution* of geostationary estimates
- Better *accuracy* of microwave estimates

Satellite Rainfall Estimates

Products	Time Res	Space Res	Existence	PM	Gauge
CMORPH	Daily	0.25 deg	2002-Pres	Y	N
NRL	3-hourly	0.25 deg	2003-2006	Y	N
PERSIANN	3-hourly	0.25 deg	2000-2006	Y	N
TRMM-3B42	3-hourly	0.25 deg	1998-Pres	Y	Y
TRMM-3B42RT	3-hourly	0.25 deg	2002-Pres	Y	N
CPC-RFE	Daily	0.1 deg	2001-Pres	Y	Y
CPC-ARC	Daily	0.1 deg	1995-Pres	N	Y
GPCP-1DD	Daily	1.0 deg	1996-Pres		
TAMSAT	10-daily	~0.05 deg	1996-Pres	N	N
GPCP	Monthly	2.5 deg	1979-2008	Y	Y
CMAP	Monthly	2.5 deg	1979-2010	Y	Y
TRMM-3B43	Monthly	2.5 deg	1998-Pres	Y	Y

Global Precipitation Climatology Project (GPCP)

- **Merged satellites with gauge**
- **2.5° spatial resolution**
- **monthly rain rate**
- **Also 1-degree daily(1DD)**
- **1979-2008 (monthly)**
- **1997-2008(1DD)**

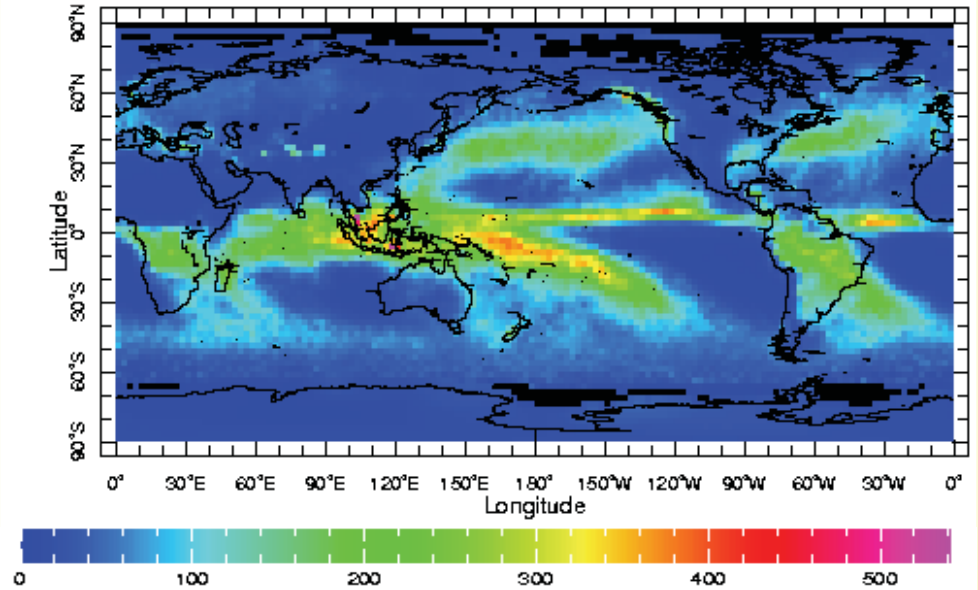


http://cics.umd.edu/~yin/GPCP/main.html

CPC-Merged Analysis of Precipitation (CMAP)

- **Merged satellites, numerical model predictions and gauge observations**
- **2.5° spatial resolution**
- **monthly total rain**
- **Also 5-day total**
- **1979-2010**

CMAP December Climatology(1979-2005)

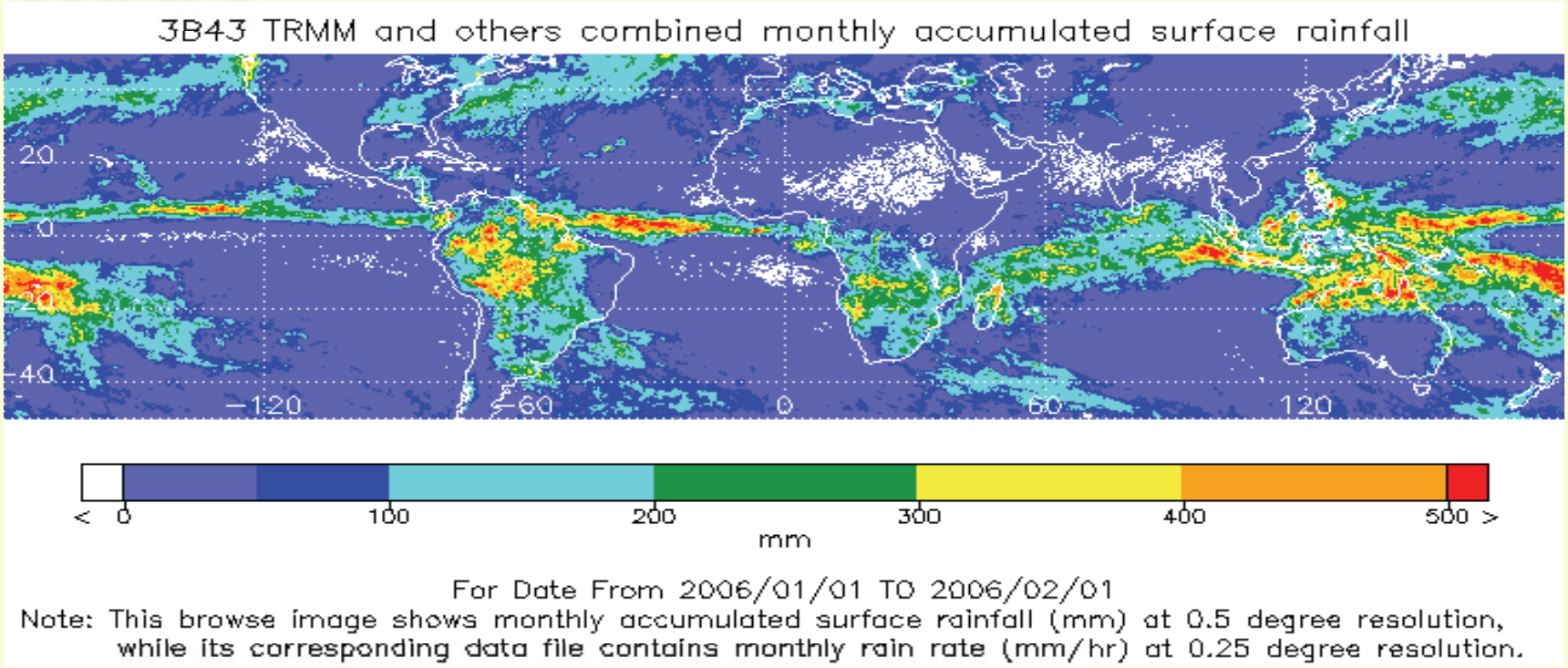


From IRI data library

http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/.monthly/.latest/.ver2/.prcp_est/

Satellite Products

TRMM



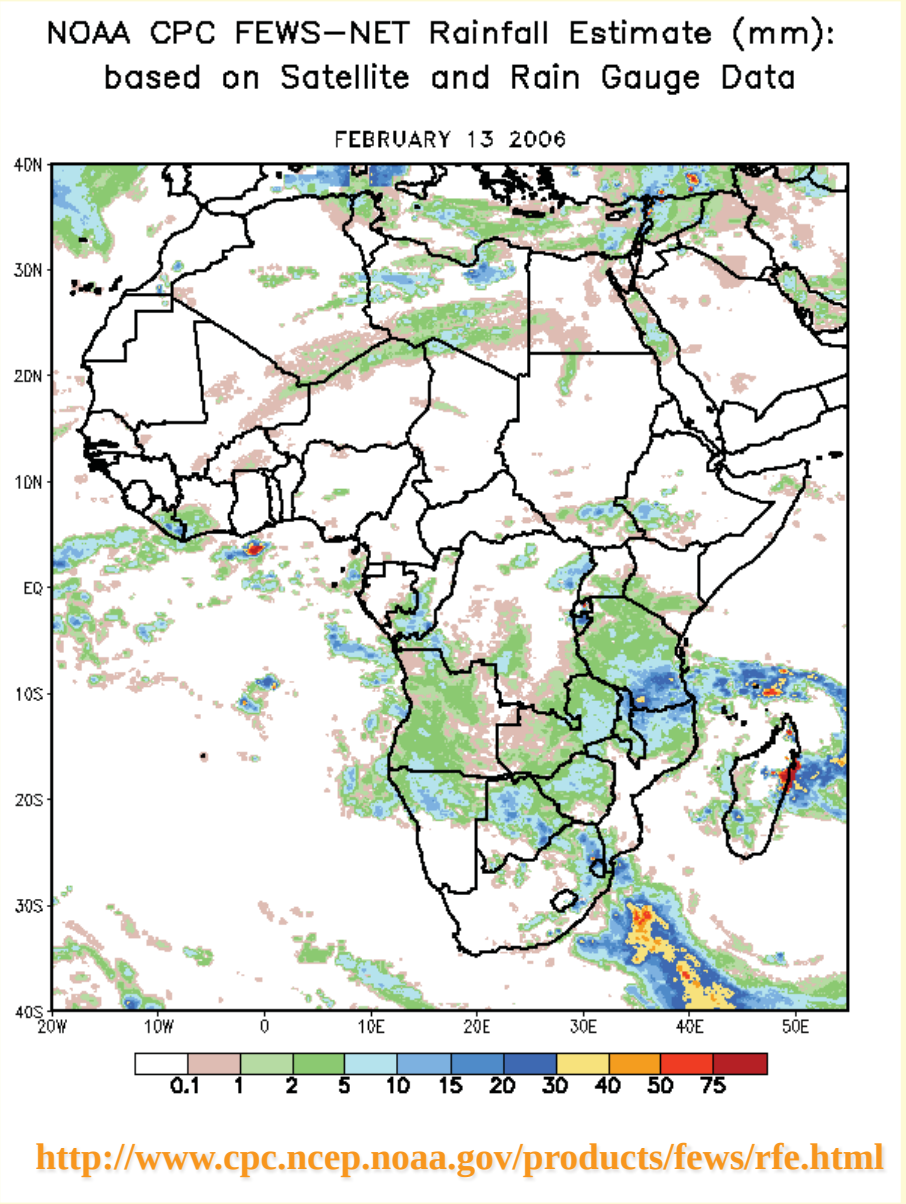
- **Active and passive microwave instruments**
- **0.25° spatial resolution**
- **monthly total rain**
- **Also 3-hourly**
- **1998-current**

http://disc.sci.gsfc.nasa.gov/data/datapool/TRMM/01_Data_Products/02_Gridded/07_Monthly_Other_Data_Source_3B_43/index.html

Satellite Products

RFE

- **Merged satellites and gauge**
- **0.1° (11 km) spatial resolution**
- **Daily total rainfall**
- **RFE1: 1995-2000**
- **RFE2: 2002-current**



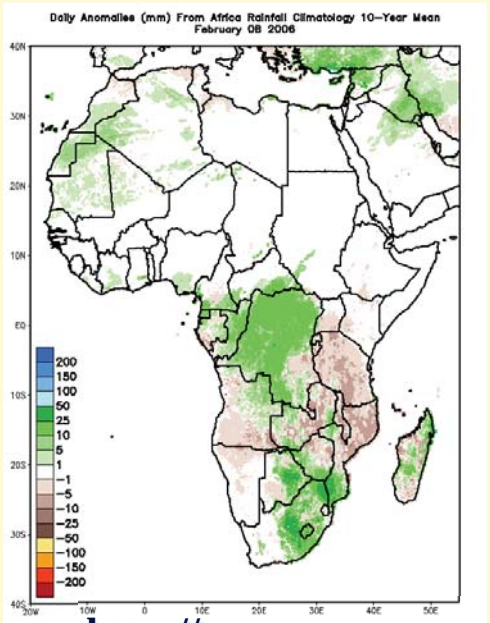
http://www.cpc.ncep.noaa.gov/products/fews/rfe.html

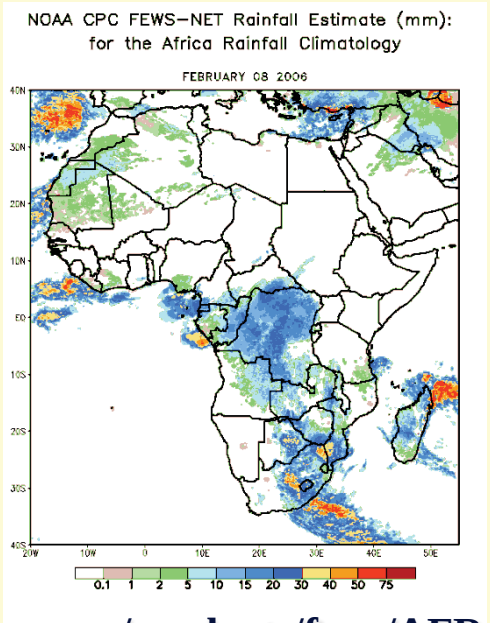
Africa Rainfall Estimate Climatology (ARC)

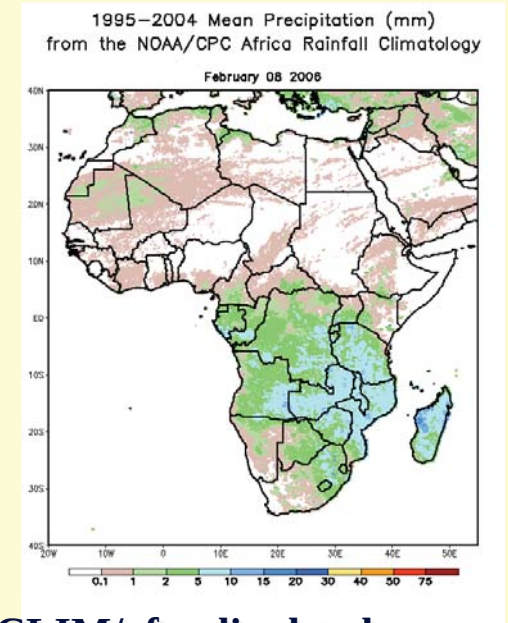
0.10-degree (11km) daily, combined IR and Gauge

1995-current

Daily







http://www.cpc.ncep.noaa.gov/products/fews/AFR_CLIM/afr_clim.html

Latest Daily Anomaly (Difference Between Mean 1995-2004 and Current)

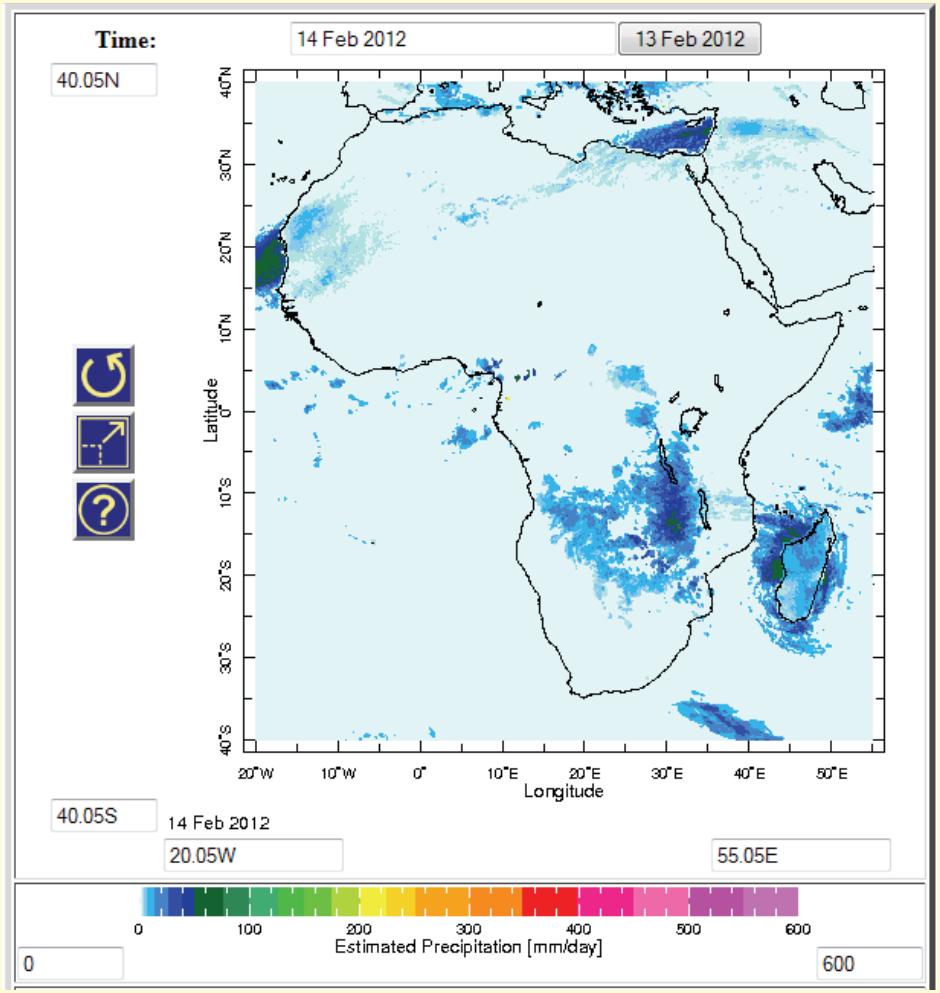
Current

10 Yr Mean

Africa Rainfall Estimate Climatology (ARC2)

0.10-degree (11km) daily, combined IR and Gauge

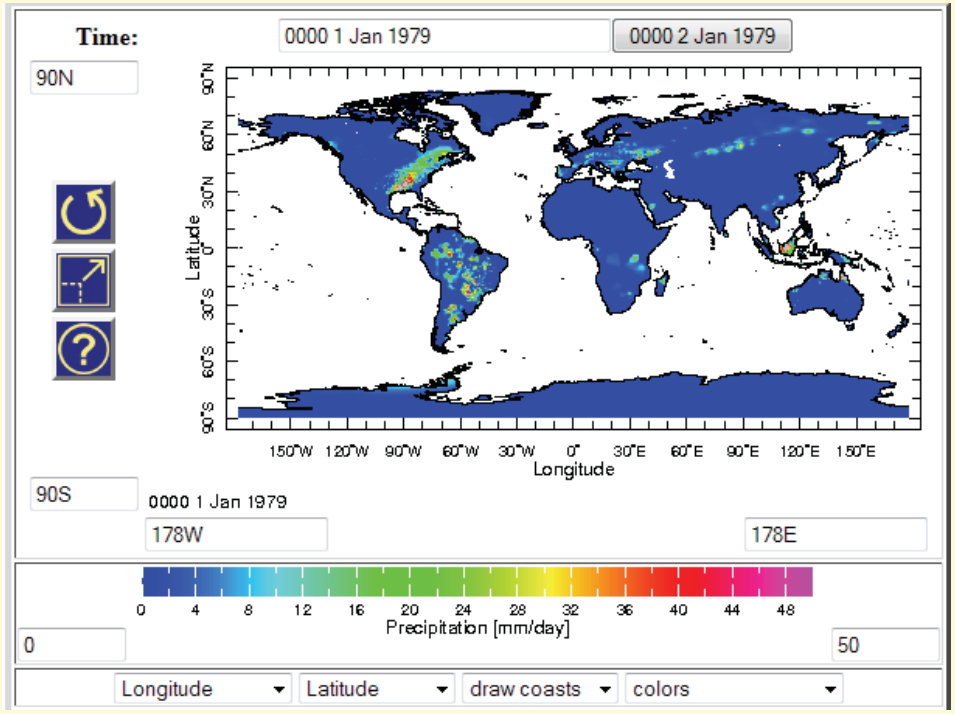
1983-current



http://iridl.ldeo.columbia.edu/
SOURCES/.NOAA/.NCEP/.CPC/.FEWS/.Africa/.DAILY/.ARC2/.daily/.est_prc

NOAA CPC Unified Precipitation

0.5-degree daily, 1 Jan 1979 – 31 Dec 2005 (RETRO); 1 Jan 2006 to present (REALTIME)



The Climate Prediction Center (CPC) Unified Gauge-Based Analysis of Global Daily Precipitation is an optimal interpolation objective analysis of global daily station precipitation data available at the CPC. It is divided into a retrospective version (RETRO) covering 1979 to 2005, derived from more than **30,000** gauges, and a real-time version (REALTIME) covering 2006 to present, derived from approximately **17,000** gauges. The grid resolution is 0.5 deg. lat/lon. The data set also includes information on the gauge network density and country-to-country variations in the daily reporting period.

http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.UNIFIED_PRCP/.GAUGE_BASED/.GLOBAL/.v1p0/.RETRO/.rain/

Validation of Rainfall Products

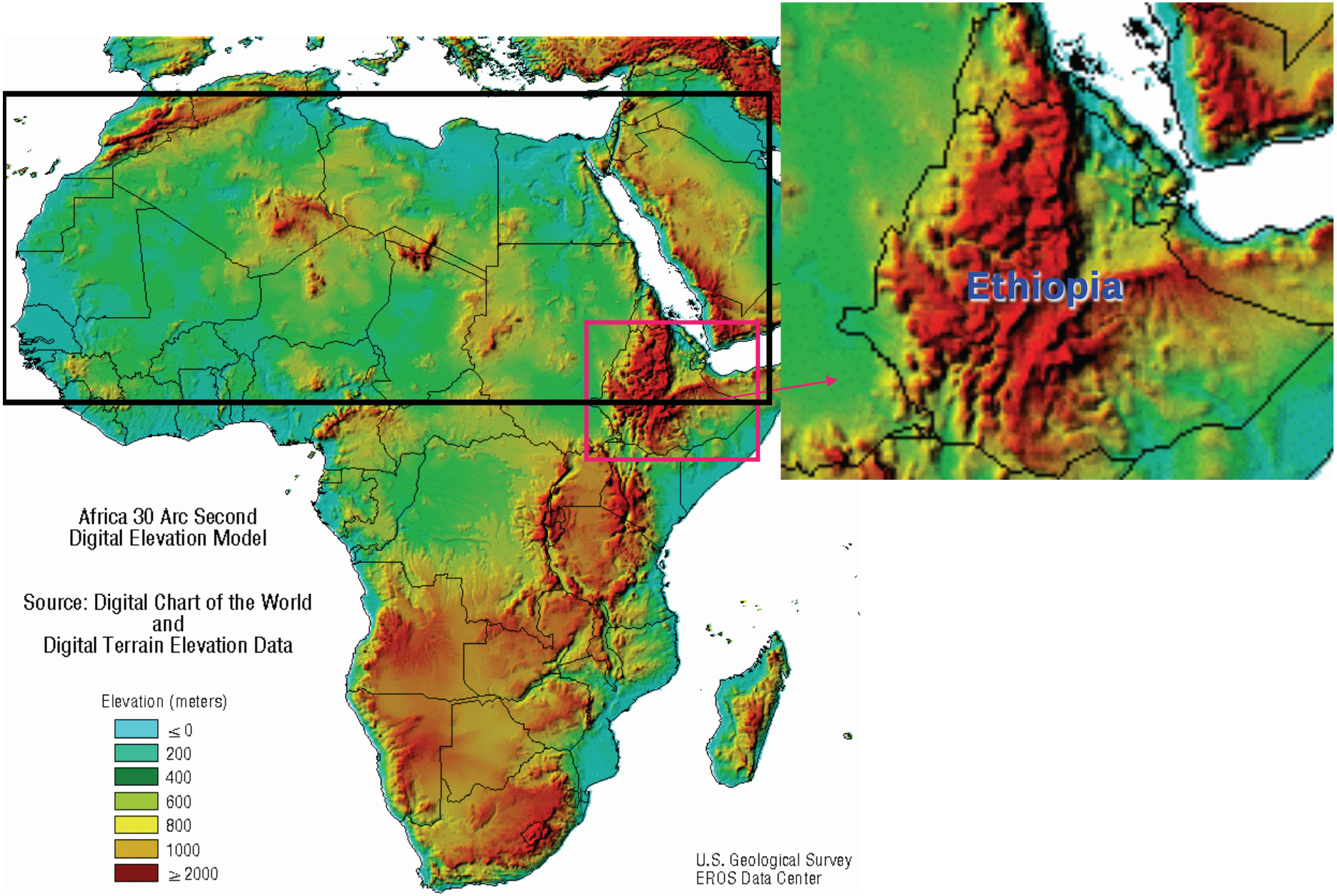
Validation:

Comparing Rainfall Estimates

with

Rain Gauge Data

Validation of Rainfall Products

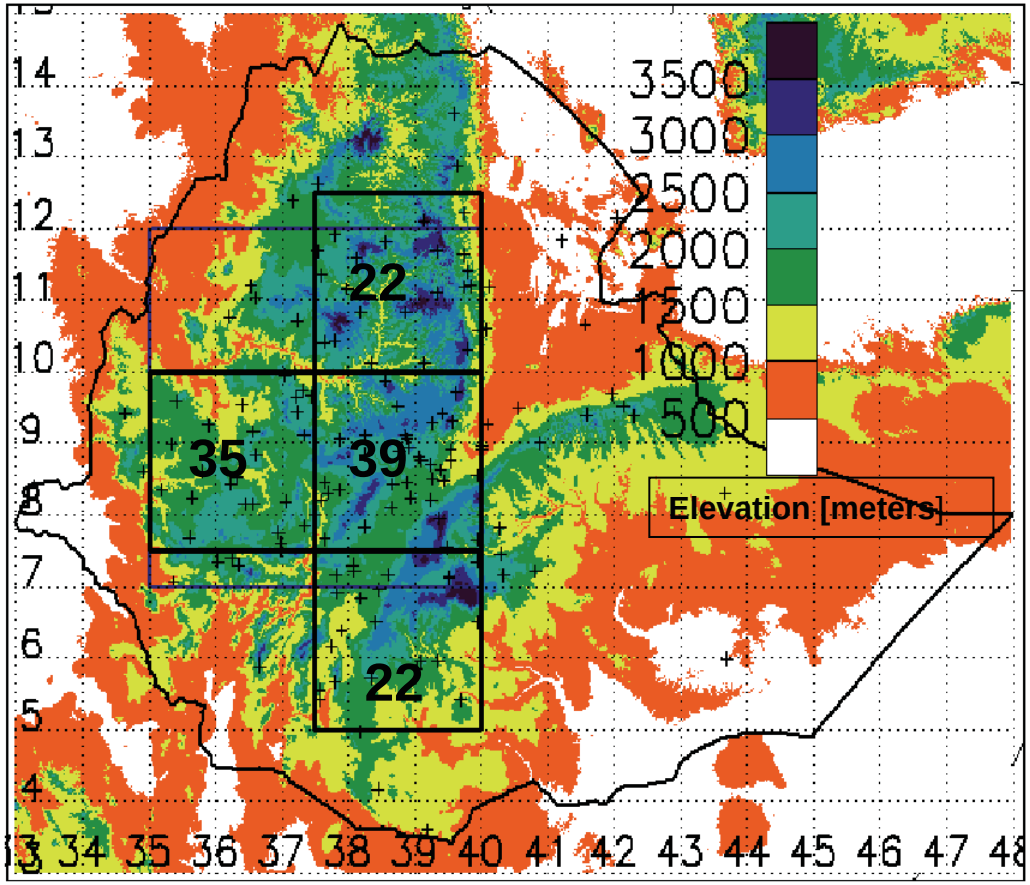


Validation of Rainfall Products

- 120 Stations used

- Gauge data gridded using Climate Aided Interpolation

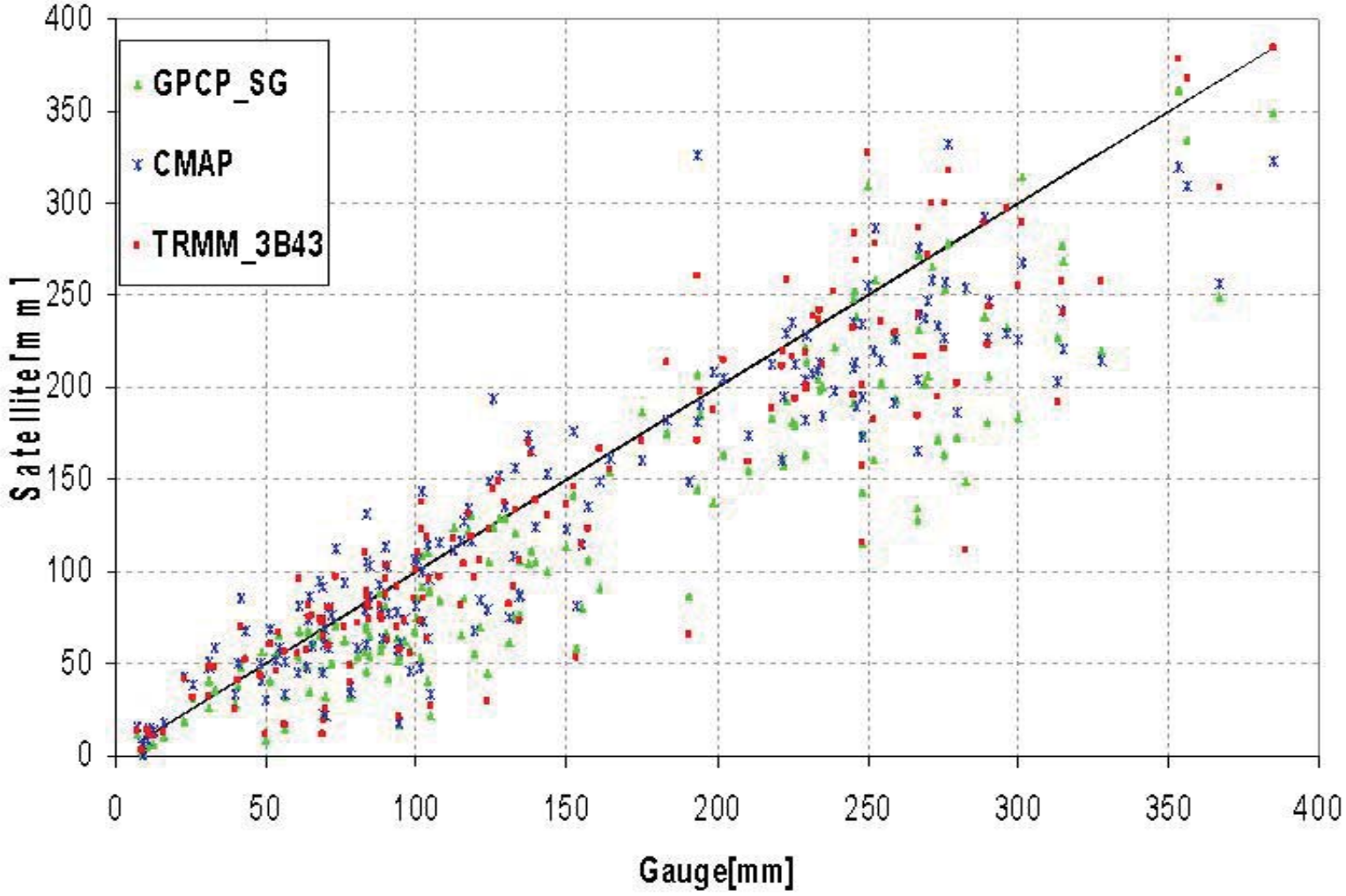
  - Kriging for interpolating the means



Topography and distribution of gauges. The four 2.5 degree boxes are used for at 2.5 degree resolution, and the number of gauges in each box is given. Stations in the larger box is used for validation at 1-degree resolution.

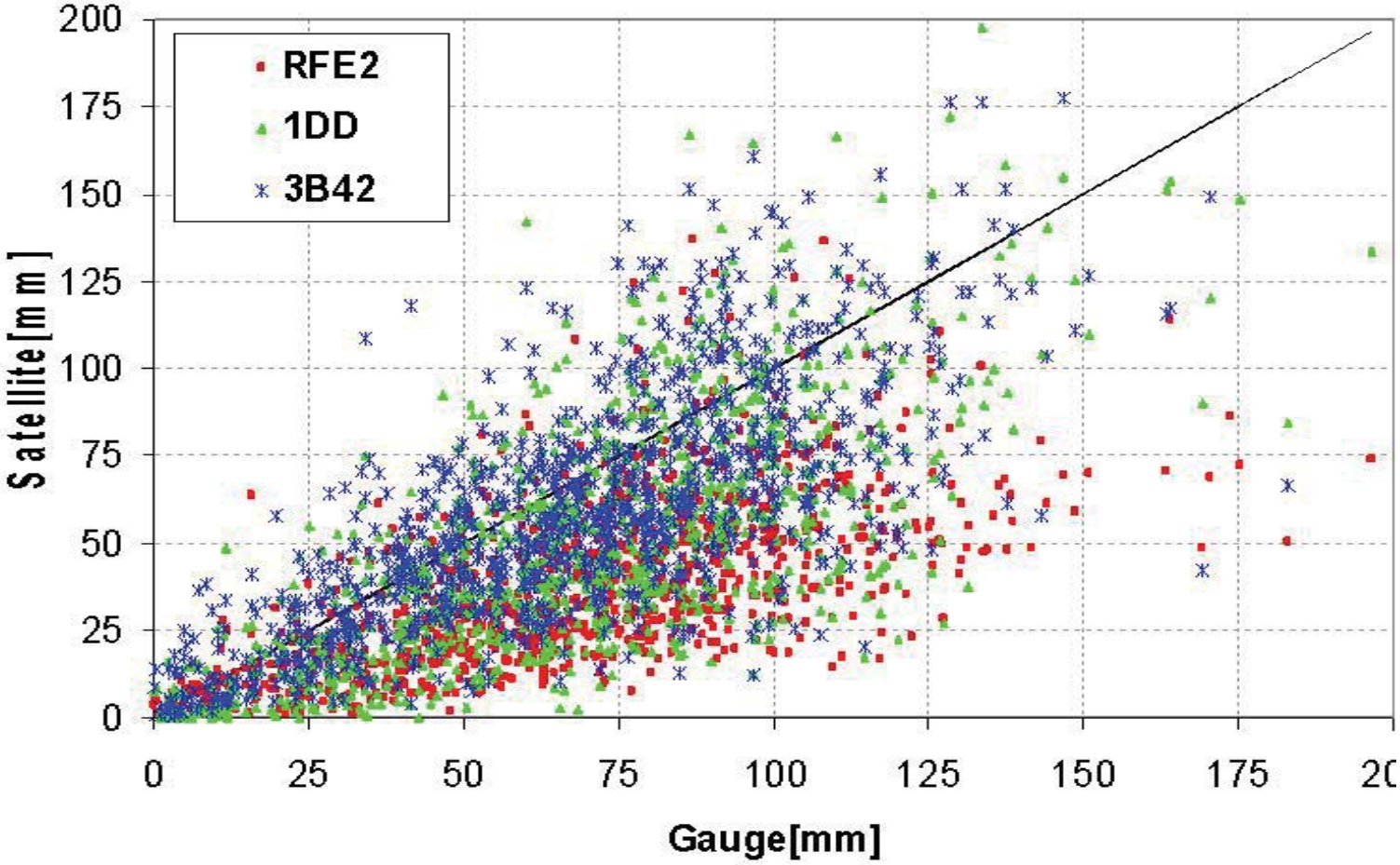
Validation of Rainfall Products

Monthly at 2.5-degree



Validation of Rainfall Products

10-day total at 1º x 1º



Comparison of CPC-RFE2, GPCP-1DD & TRMM-3B42

Validation of Rainfall Products

The following statistics were used to evaluate the accuracy of the rainfall estimate products to retrieve rainfall: coefficient of determination (R^2), mean error (ME), standard deviation (Stdv), root mean square error (RMSE), mean absolute error (MAE), and bias.

$$ME = \frac{1}{N}\sum(G-R)$$

$$RMSE = \sqrt{\frac{\sum(G-R)^2}{N}}$$

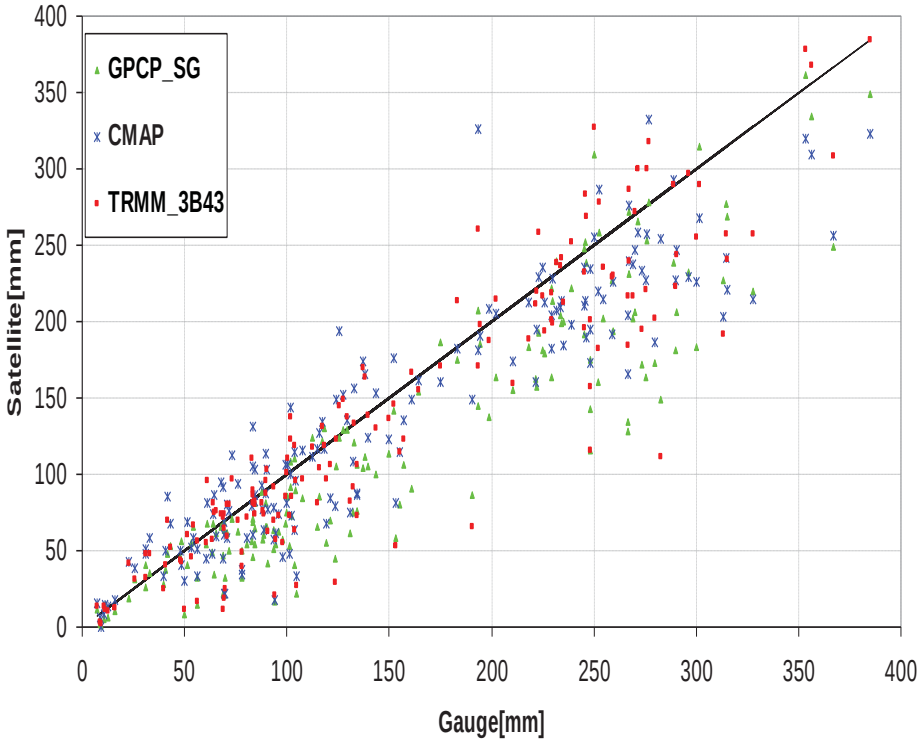
$$MAE = \frac{1}{N}\sum|(G-R)|$$

$$Bias = \frac{\sum G}{\sum R}$$

Where R = reference rain gauge observation, G = rainfall estimate product, and N = number of data pairs. ME and MAE are in mm while R^2, Stdv, RMSE and Bias are unit-less.

Validation of Rainfall Products

Monthly at 2.5-degree

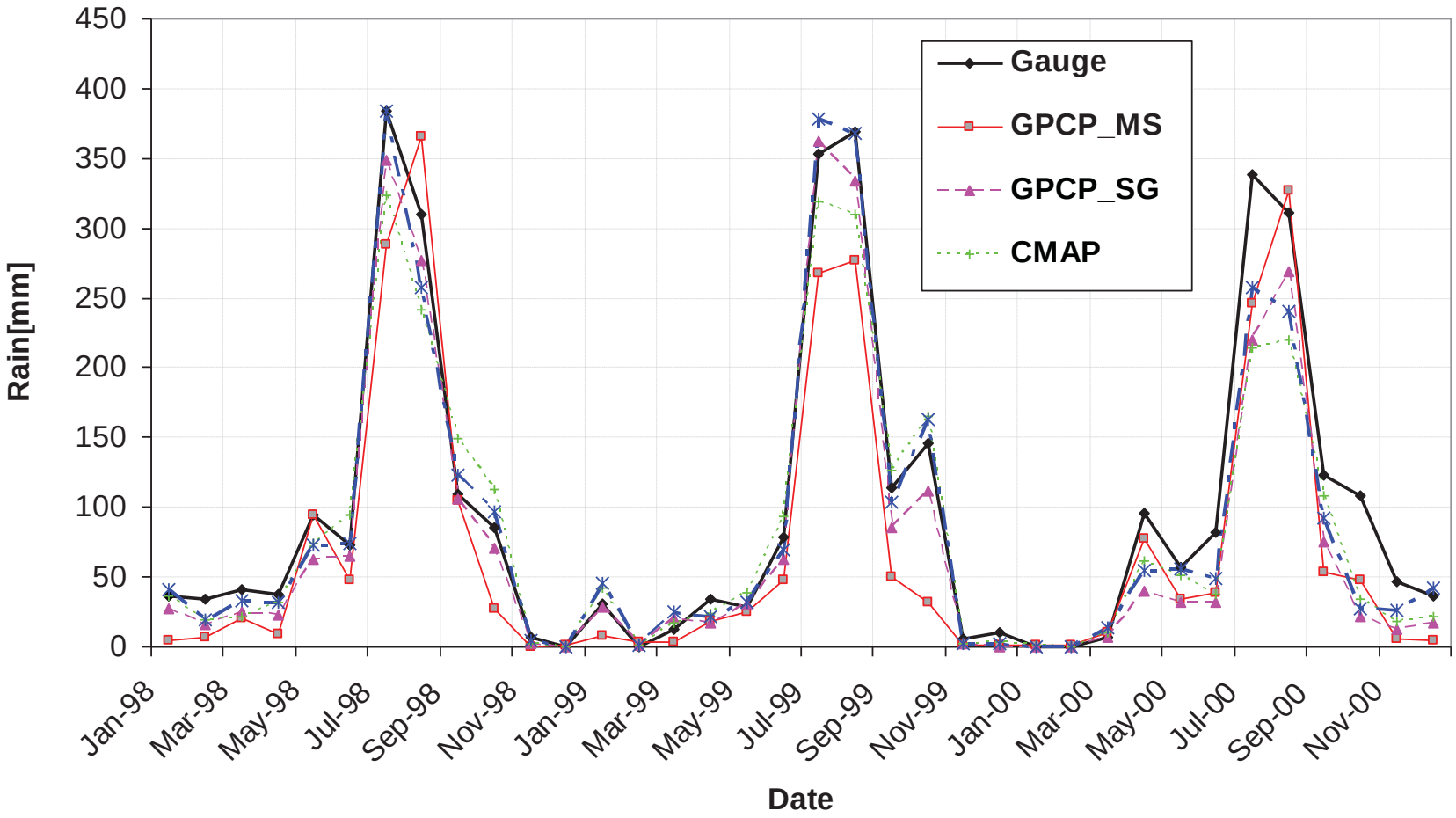


N = 360	GPCP	CMAP	3B43
CC	0.92	0.92	0.92
Bias	0.80	0.91	0.92
ME	-30	-12	-12

Data: 1998-2004

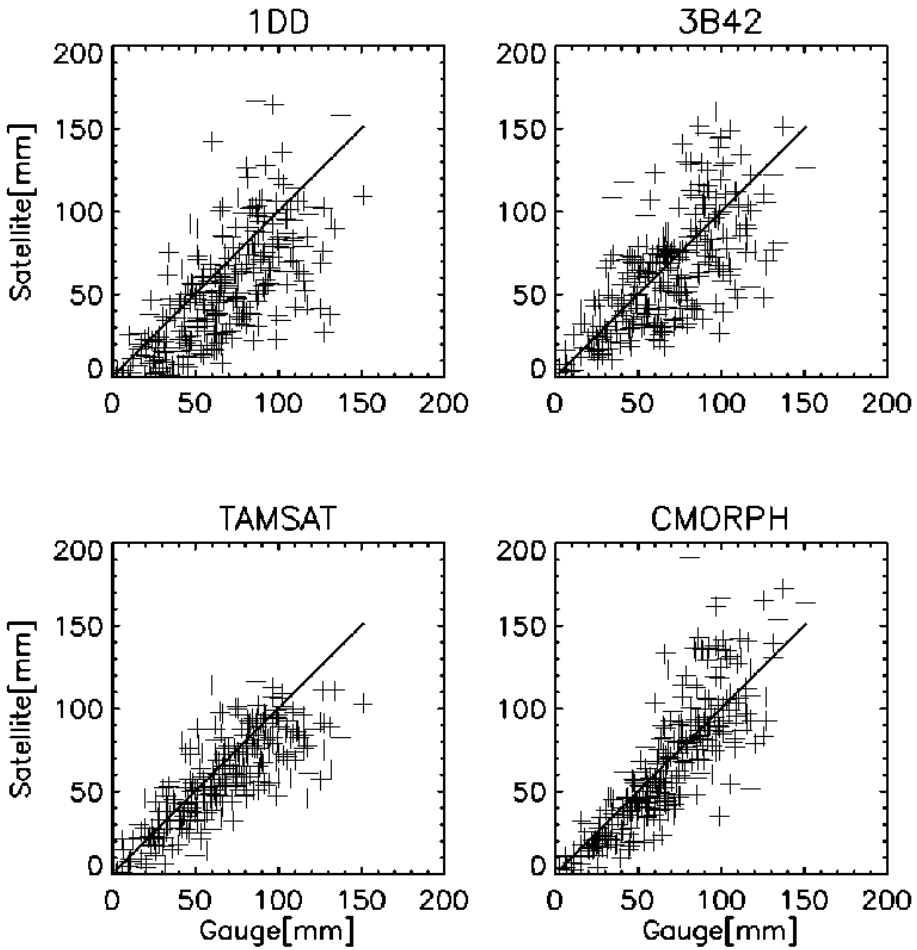
Validation of Rainfall Products

Monthly at 2.5-degree



Validation of Rainfall Products

10 Days at 1ºx1º



10-day @ 1º x 1º

N=306	1DD	3B42	TAMSAT	C M O RPH
CC	0.68	0.68	0.79	0.83
Bias	0.77	0.94	0.86	0.98
ME	-16	-4	-9	-1

Validation of Rainfall Products

Daily @ 0.25-deg	RFE	PERS	NRL	3B42	3B42RT	CMORPH
CC	0.26	0.40	0.36	0.39	0.37	0.32
Bias	0.60	1.54	0.85	0.84	0.83	0.91

10-Daily @ 1 deg	RFE	1DD	3B42T	3B42	TAMSAT	CMORPH
CC	0.66	0.71	0.72	0.72	0.79	0.83
Bias	0.55	0.72	0.95	0.87	0.93	0.98

Monthly @ 2.5-deg	GPCP	CMAP	3B43
CC	0.92	0.92	0.92
Bias	0.80	0.91	0.92

Improving Rainfall Estimates

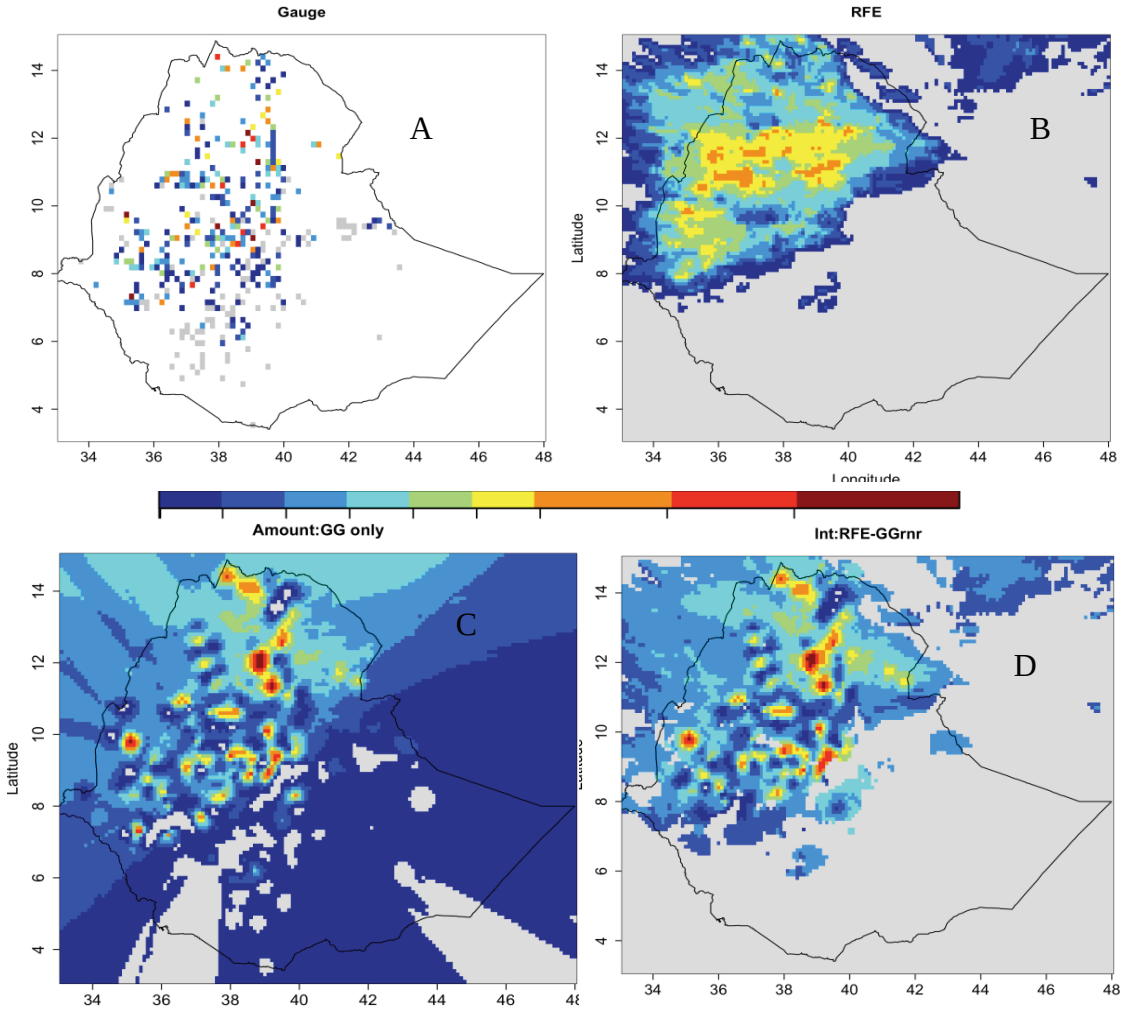
Calibration:

Integrating Rainfall Gauges

within

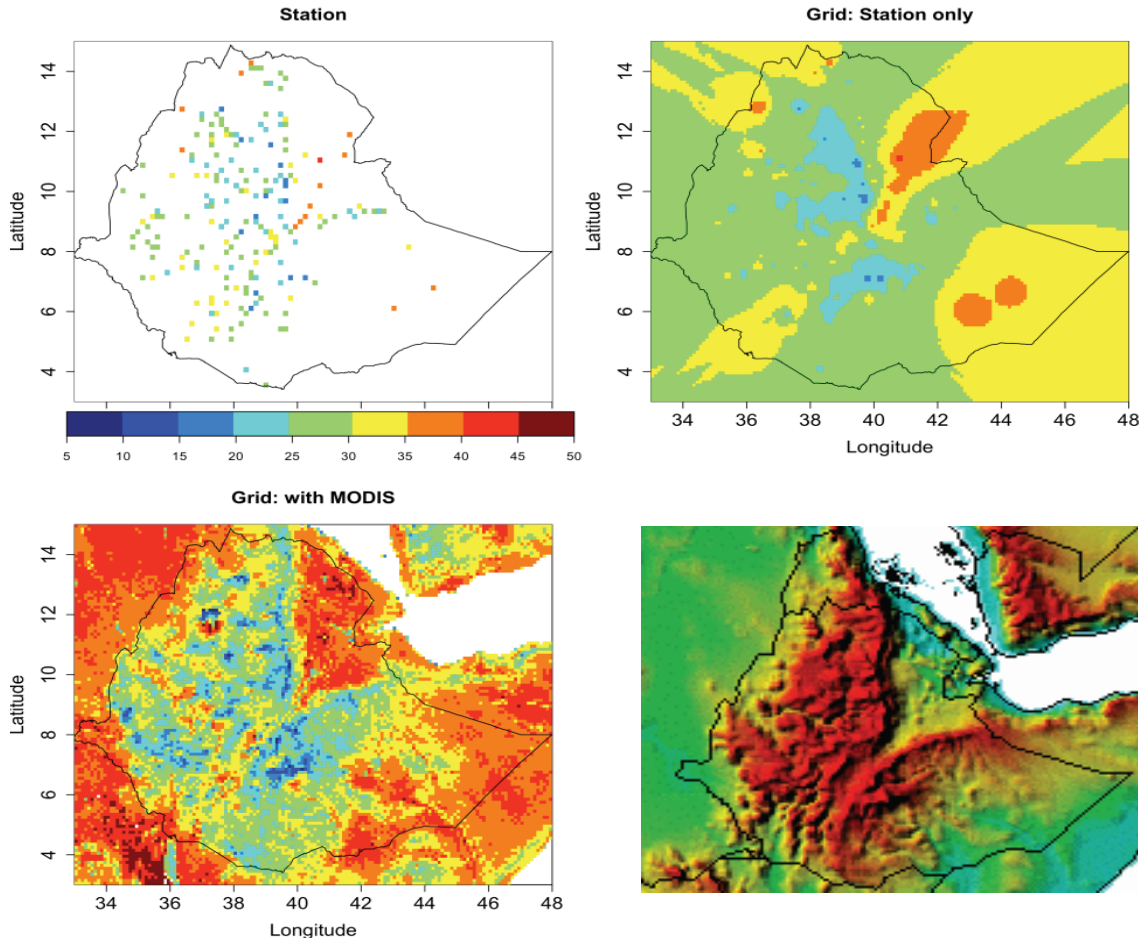
Rainfall Estimates Derived from Satellites

Improving Rainfall Estimates



Comparison of rain gauge data (A), satellite estimates (B), gauge-only gridded products(C), and combined gauge-satellite product (D), over Ethiopia for 7 July 2003. All products have spatial resolution of 0.1º lat/long

Improving Temperature



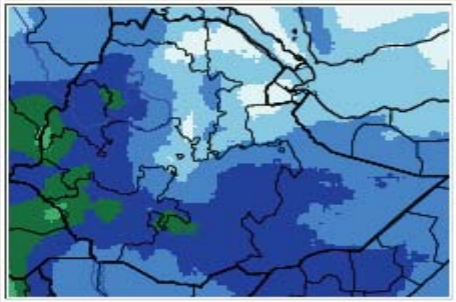
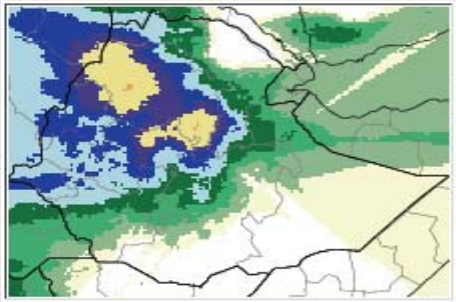
Maximum temperature for 2nd dekad of April 2000. Top-left panel is station data, while top-right panel is interpolated station data. Bottom-left panel is station data combined with dekadal averages of MODIS LST and DEM. The bottom right panel is topography included for reference.

Ethiopian Meteorology Agency

NMA ብሔራዊ ሚቲዎሮሎጂ ኤጀንሲ NATIONAL METEOROLOGY AGENCY

Climate Analyses and Applications Map Room

http://www.ethiomet.gov.et/

Climate Analysis	
	Rainfall and temperature time series (1983-2010) reconstructed from station observations and remote sensing proxies. This interface allows users to view rainfall, maximum and minimum temperature climatologies and anomalies.
Climate Monitoring	
	This is a rainfall-monitoring product based on dekadal rainfall. The interface allows users to view recent rainfall with a seasonal and recent historical perspective. Time series analyses of rainfall data are generated based on user-selected parameters.

IRI