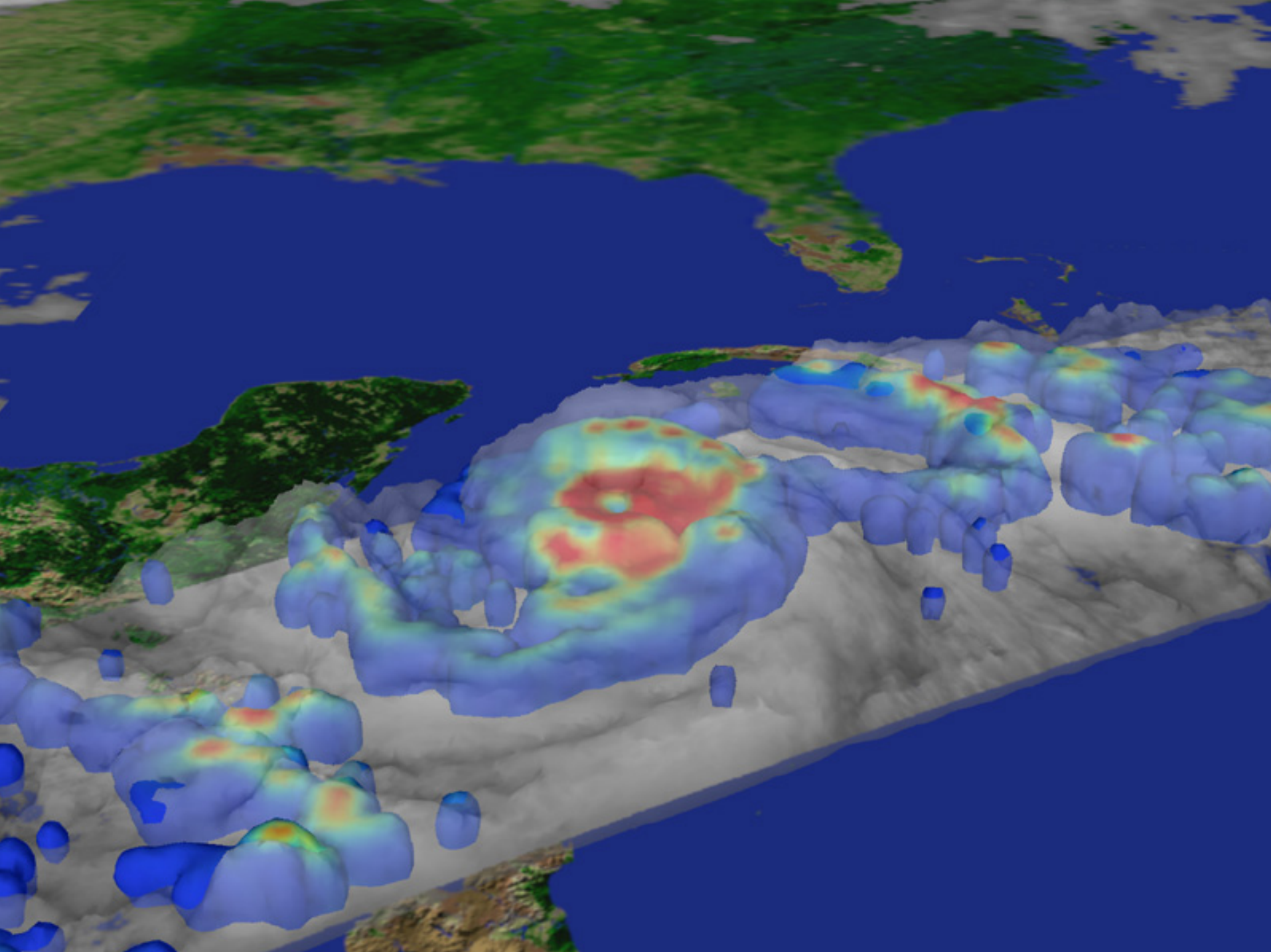
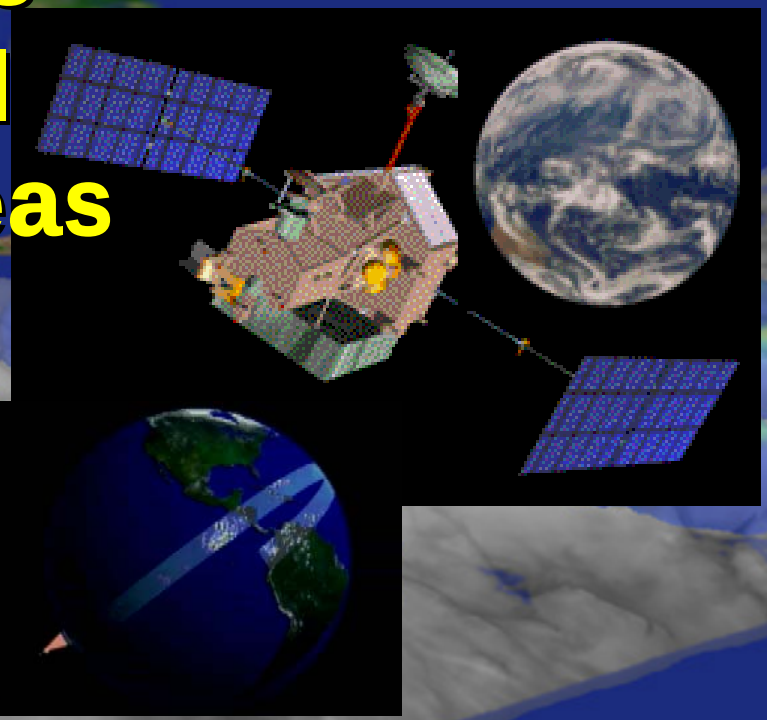


Evaluation of Satellite Estimation Techniques for Improving Rainfall Monitoring in Arid Areas



UNIVERSITY OF LOUISIANA Lafayette

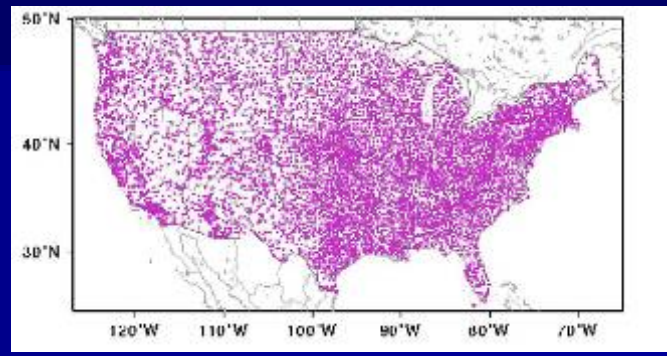
Dr. Emad Habib, Ph.D., P.E.
Department of Civil Engineering
University of Louisiana, USA

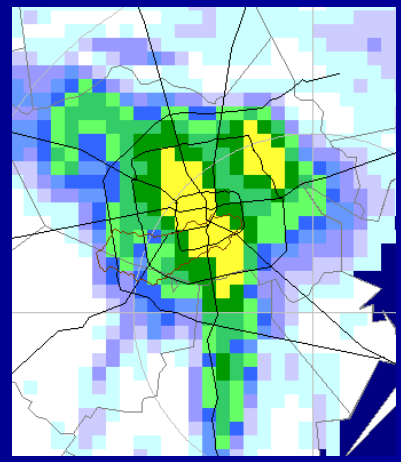
Rainfall Hazards and Benefits

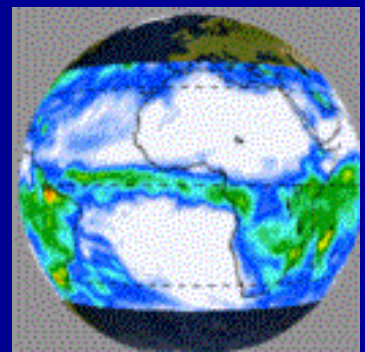
- Heavy and localized rainfall events
- Flash floods
- A potential source for fresh water

How do we monitor rain?

- Rain Gauges
  - Most direct measurements
  - They suffer from being “near-point” observations
  - They require frequent maintenance and downloads and are subject to breakdowns
- Weather radars
  - Continuous spatial and temporal coverage
  - A network of radars over large arid area is costly
- Satellites
  - Global coverage
  - Most viable in remote regions and areas with limited resources.

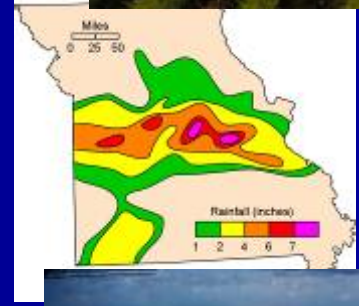






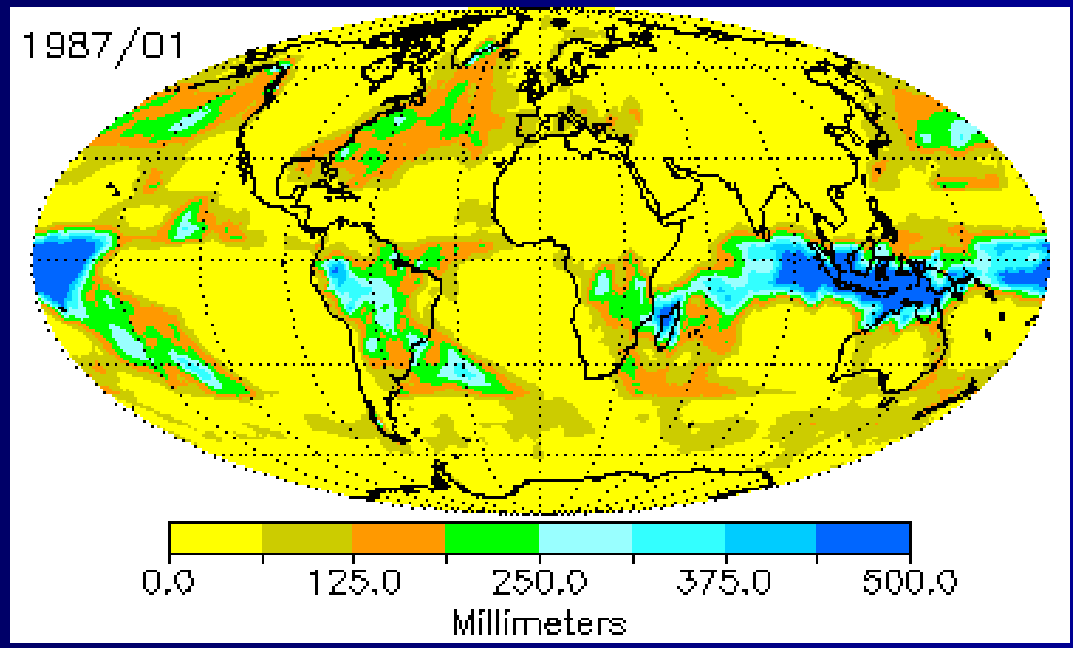
Motivation & Objectives

- Take advantage of recent advances in satellite-rainfall estimation algorithms and their potential for water resources management applications
- Satellites don't measure rainfall directly
  - Estimation algorithm
  - Uncertainty
- This study will perform an assessment of satellite algorithms for quantifying surface rainfall amounts as a potential water resource in arid areas



Satellite Rainfall Estimation Methods

- Two main approaches
  - Visible (VIS)/Infrared (IR) Algorithms
  - Microwave Algorithms



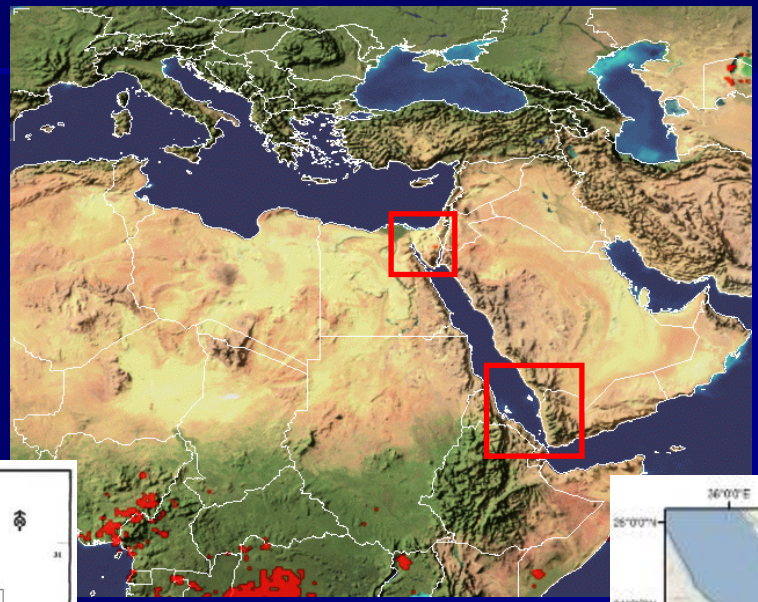
IR vs. Microwave Comparison

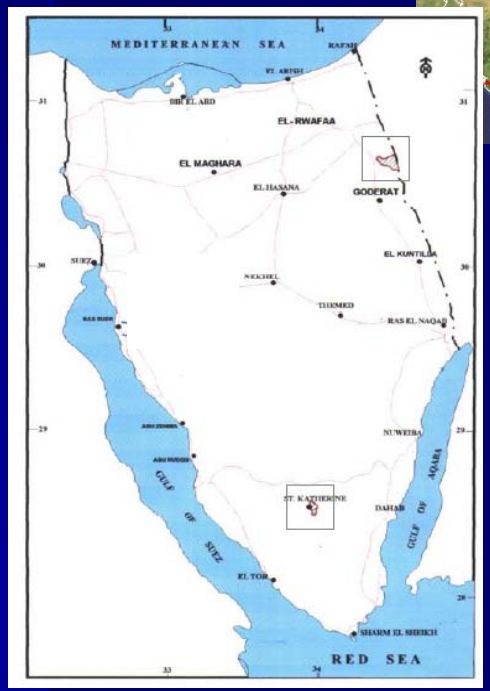
	IR	Microwave
Physics	Based on cloud-top properties; weakly related to actual rainfall rates	Based on bulk vertical cloud ice content; sensitive to moisture throughout the cloud
Resolution	4-km, 15-min (CONUS) from GEO	15-km, 2x/day from LEO

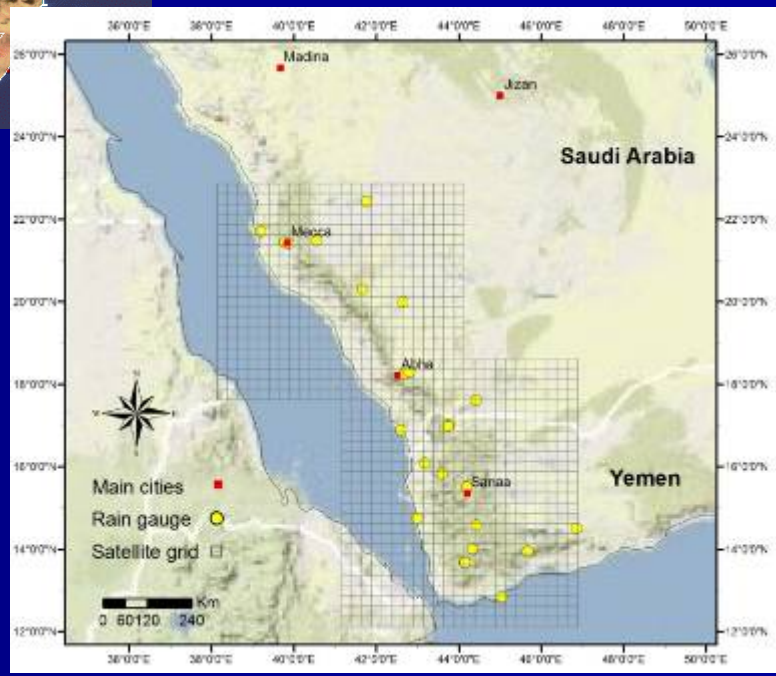
Goal:

combine IR and MW to optimize accuracy and resolution

Study Sites




MEDITERRANEAN SEA
EL-RWAFAA
EL MAGHARA
GODERAT
EL KUNTILLA
THEMED
RAS EL NAQAB
NUWEIBA
ST. KATHERINE
DAHAB
GULF OF SUEZ
GULF OF AQABA
EL TOR
SHARM EL SHEIKH
RED SEA

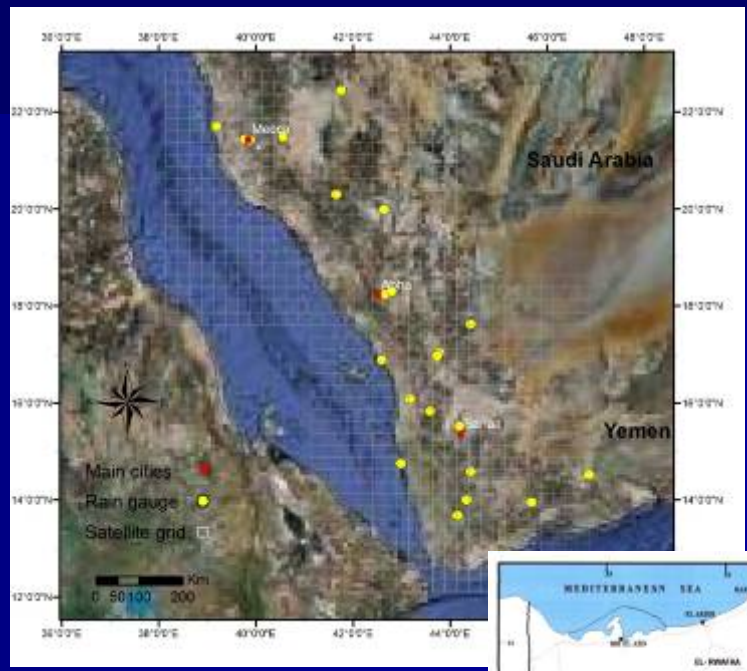

Madina
Jizan
Saudi Arabia
Mecca
Abha
Sanaa
Yemen
Main cities
Rain gauge
Satellite grid
Km
0 60120 240

Satellite Data:
TRMM Multi-sensor Estimates (TMPA)

- produced by merging MW from Tropical Rainfall Measuring Mission (TRMM) with high quality infrared (IR) precipitation
  - 0.25° × 0.25°
  - 3-hourly resolution
  - extending from 50° S - 50° N latitude

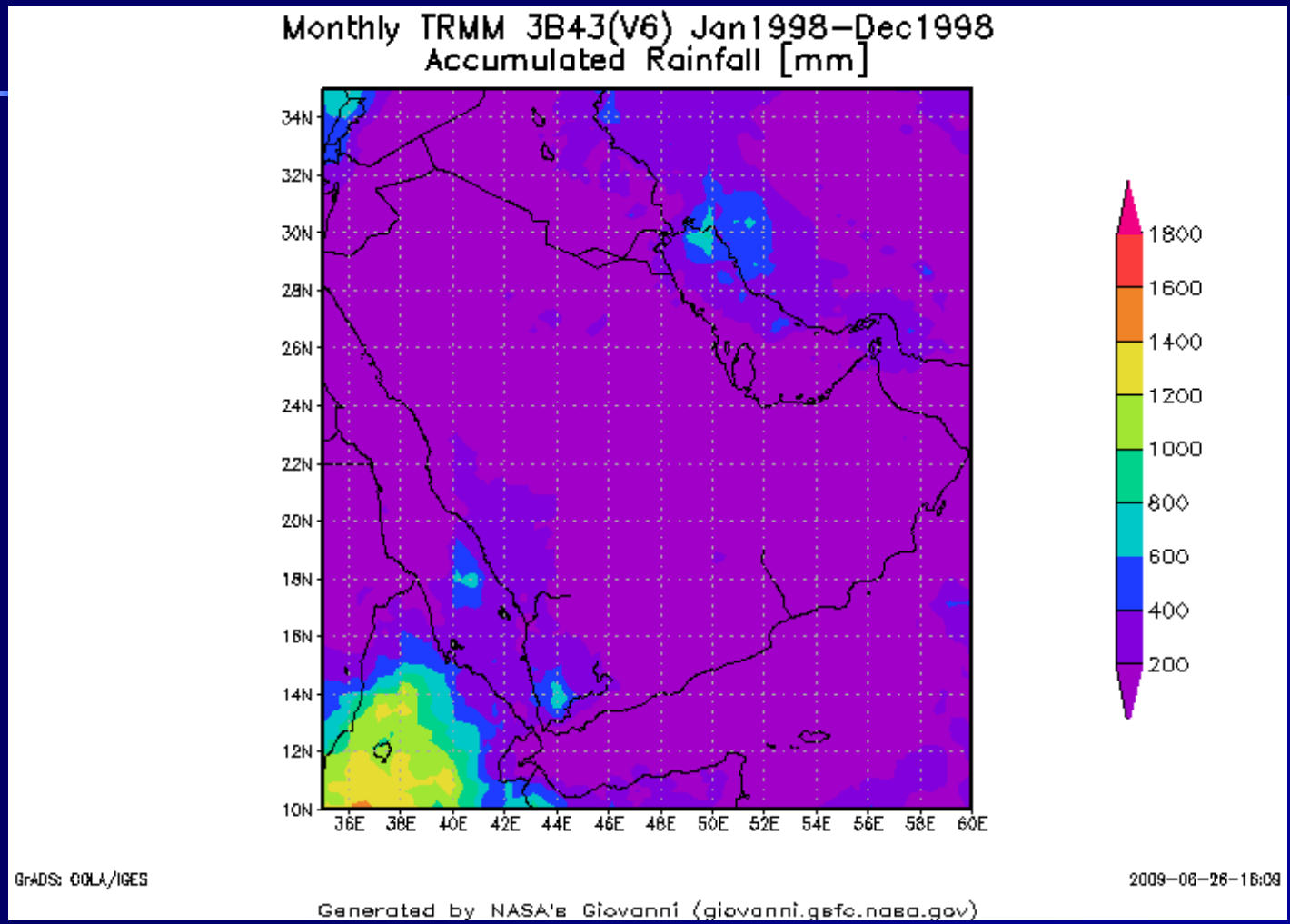
Validation Datasets: rain gauges

- Saudi Arabia and Yemen:
  - Daily & Monthly rain gauges
  - Acquired from NCDC archives
- Sinai
  - Storm-total rainfall from WRRI



Evaluation Methods

- Examination of spatial rainfall distribution
- Analysis of monthly rainfall time series
- Analysis of rainfall seasonal cycle of monthly-mean distribution
- Comparison of storm rainfall total depths
- Statistical assessment using standard measures


Monthly TRMM 3B43(V6) Jan1998–Dec1998
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1800
1600
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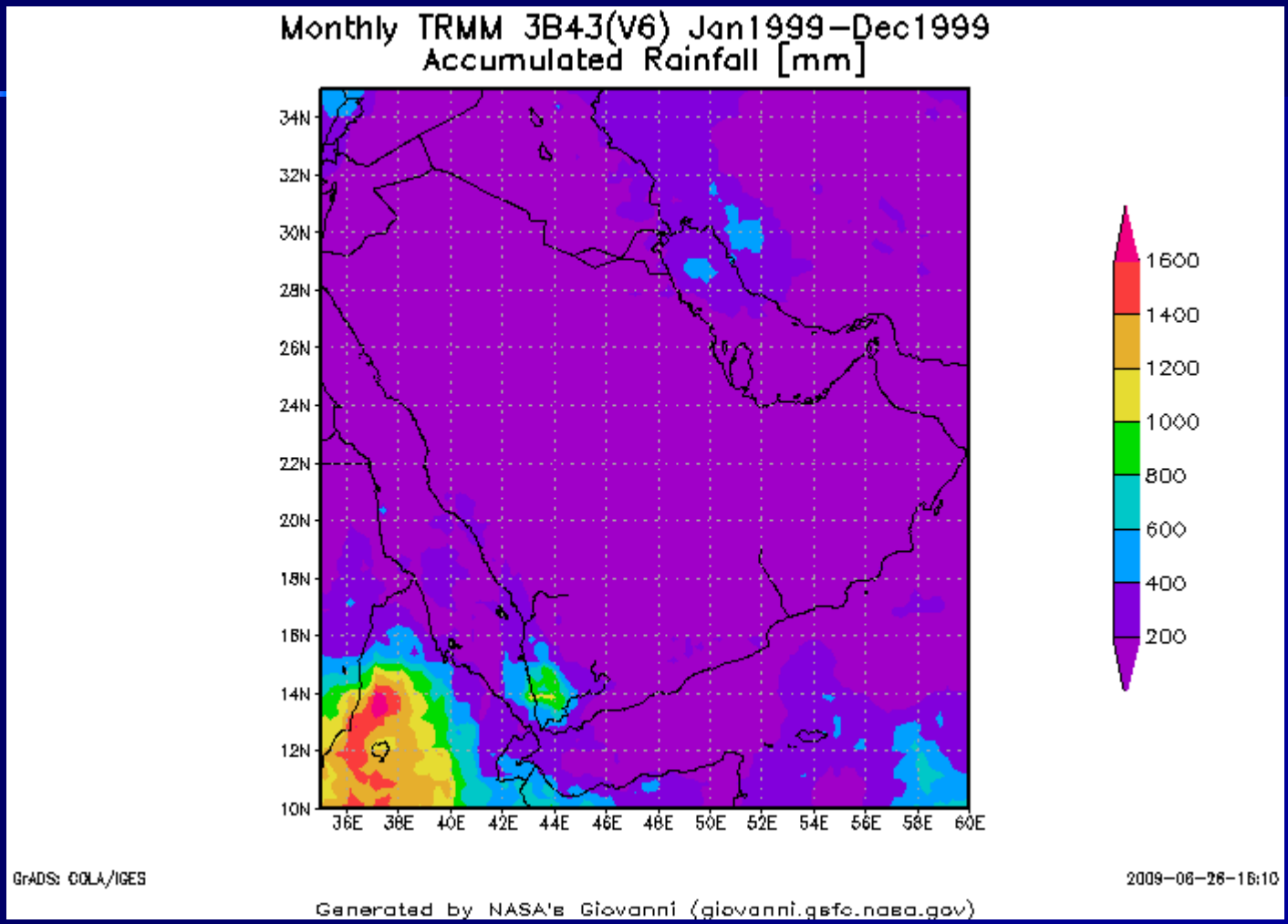
Monthly TRMM 3B43(V6) Jan1999–Dec1999
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1600
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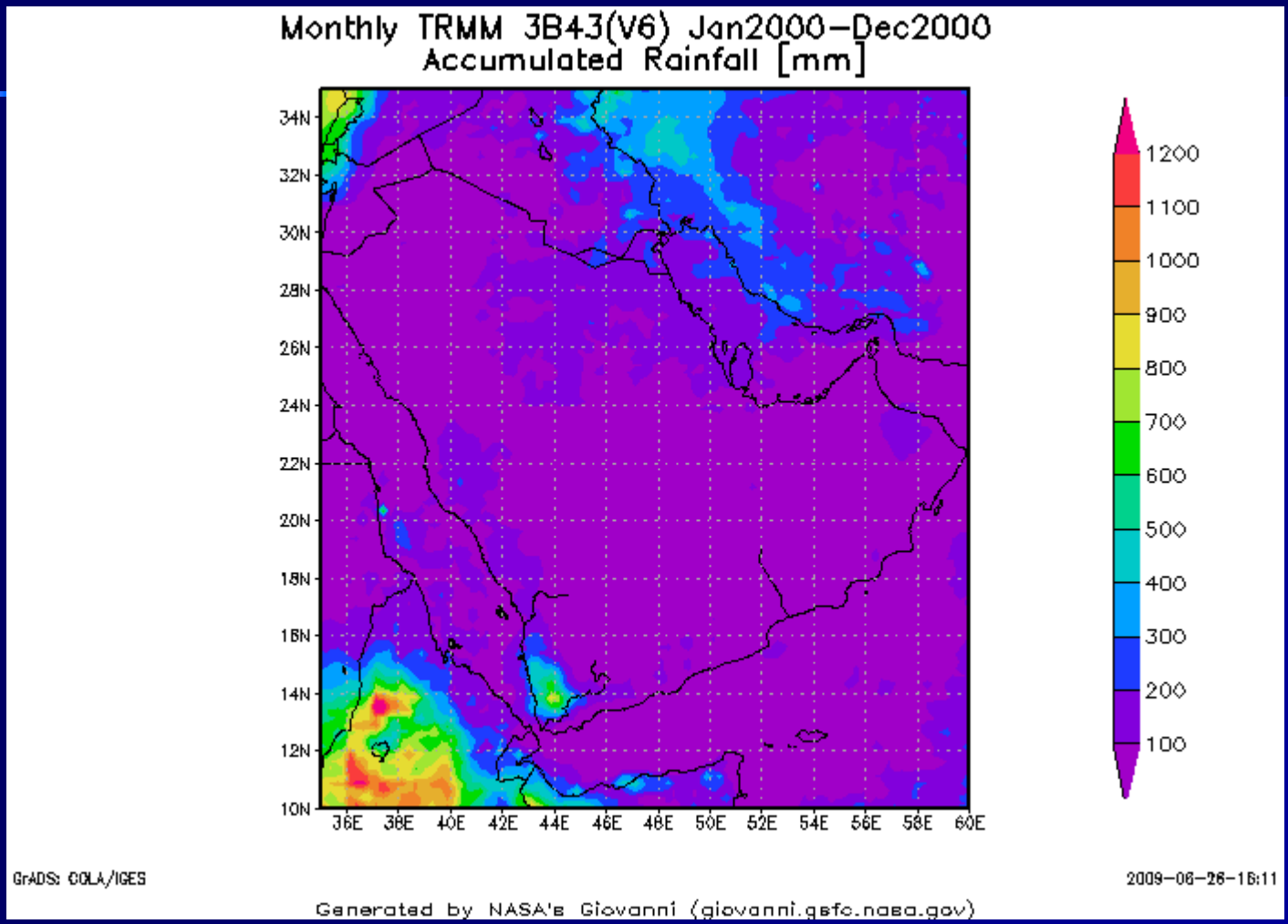
Monthly TRMM 3B43(V6) Jan2000–Dec2000
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1200
1100
1000
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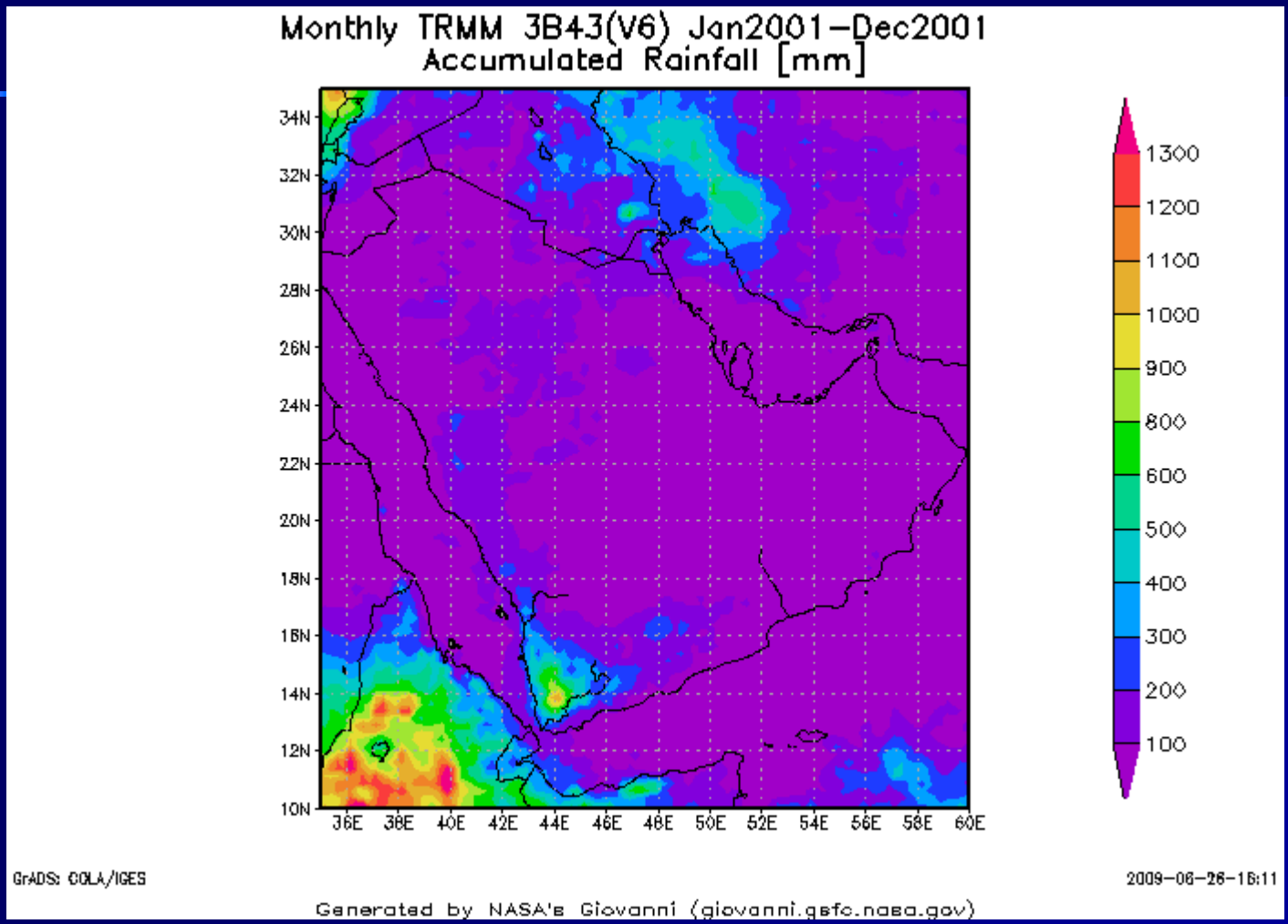
Monthly TRMM 3B43(V6) Jan2001–Dec2001
Accumulated Rainfall [mm]
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32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1300
1200
1100
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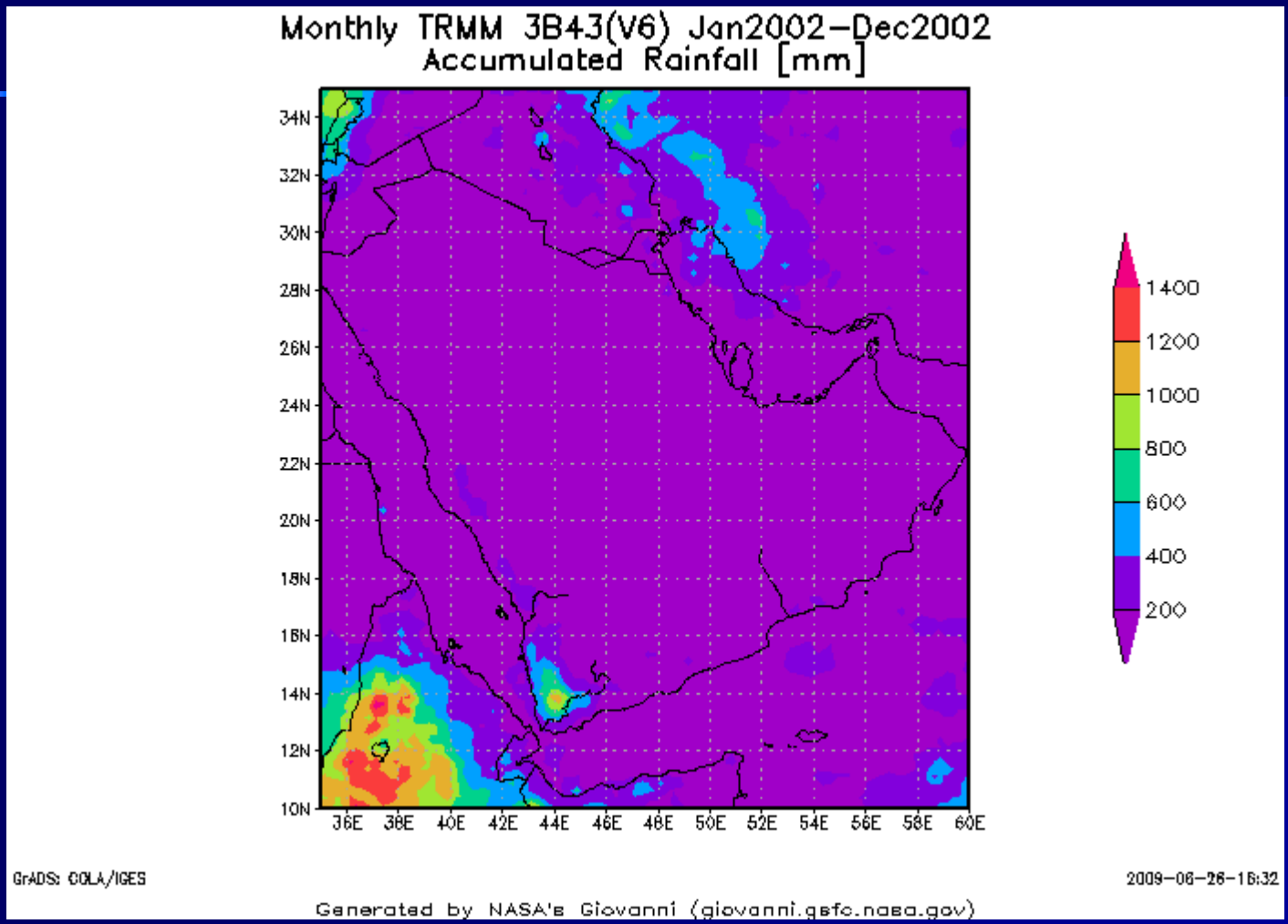
Monthly TRMM 3B43(V6) Jan2002–Dec2002
Accumulated Rainfall [mm]
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32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
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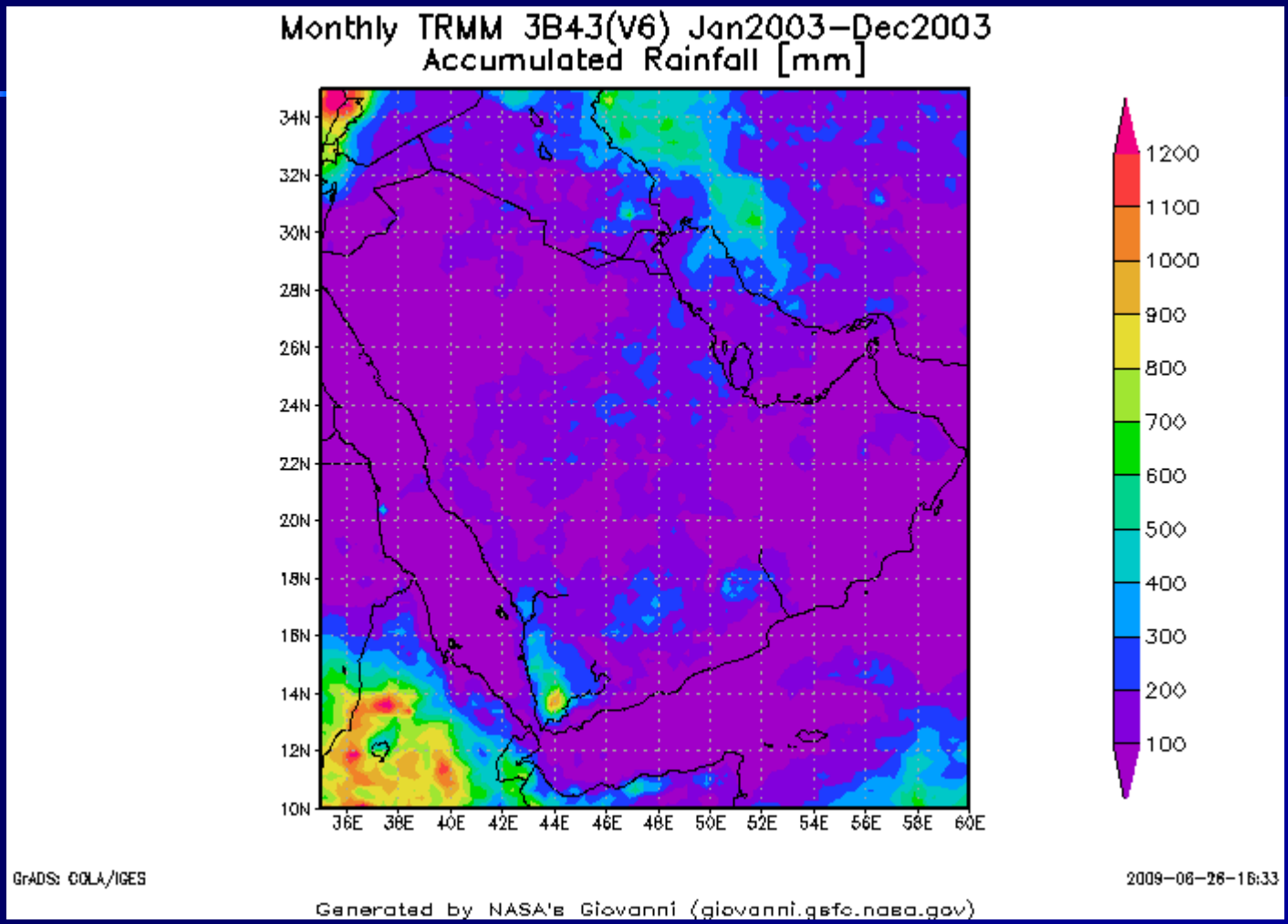
Monthly TRMM 3B43(V6) Jan2003–Dec2003
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1200
1100
1000
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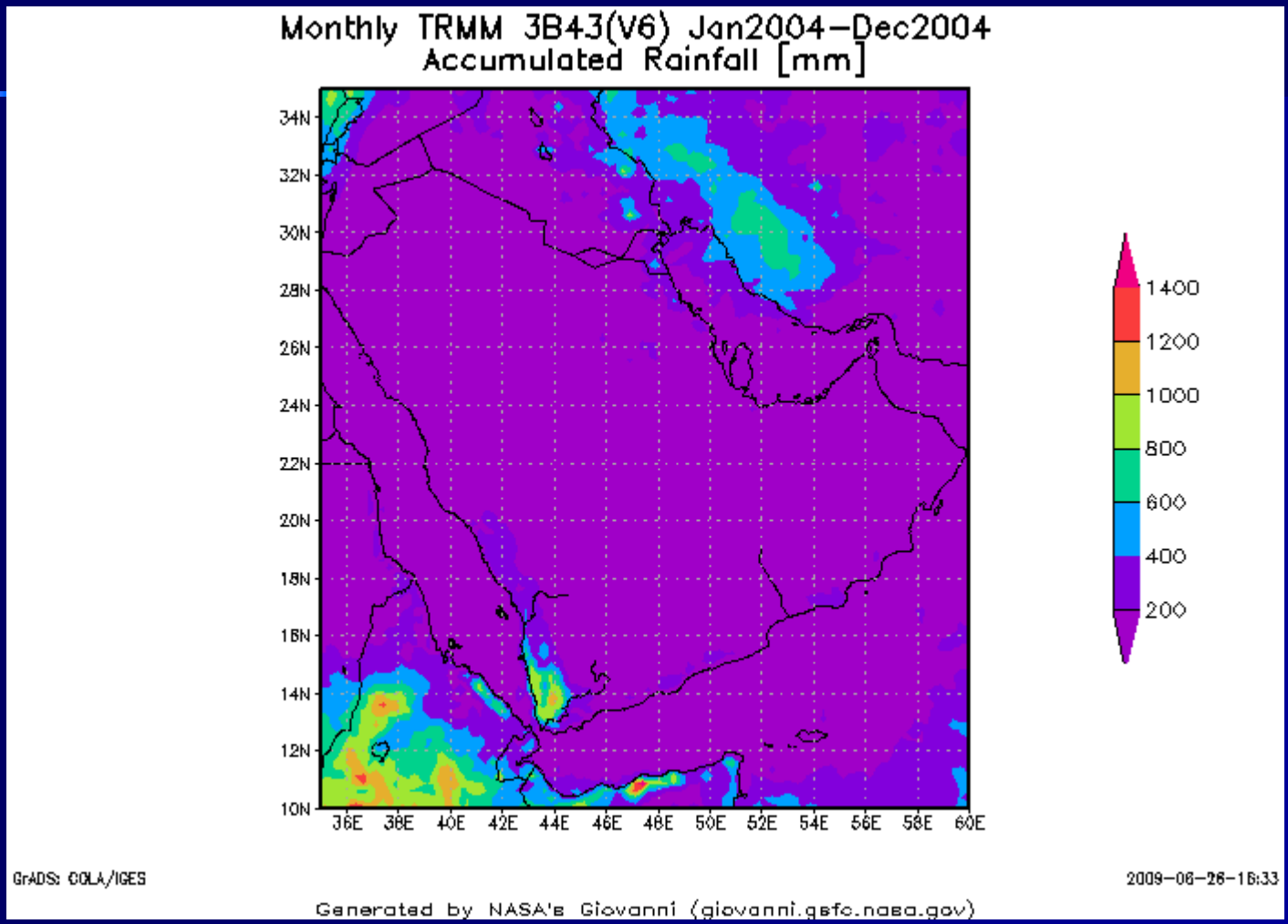
Monthly TRMM 3B43(V6) Jan2004–Dec2004
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
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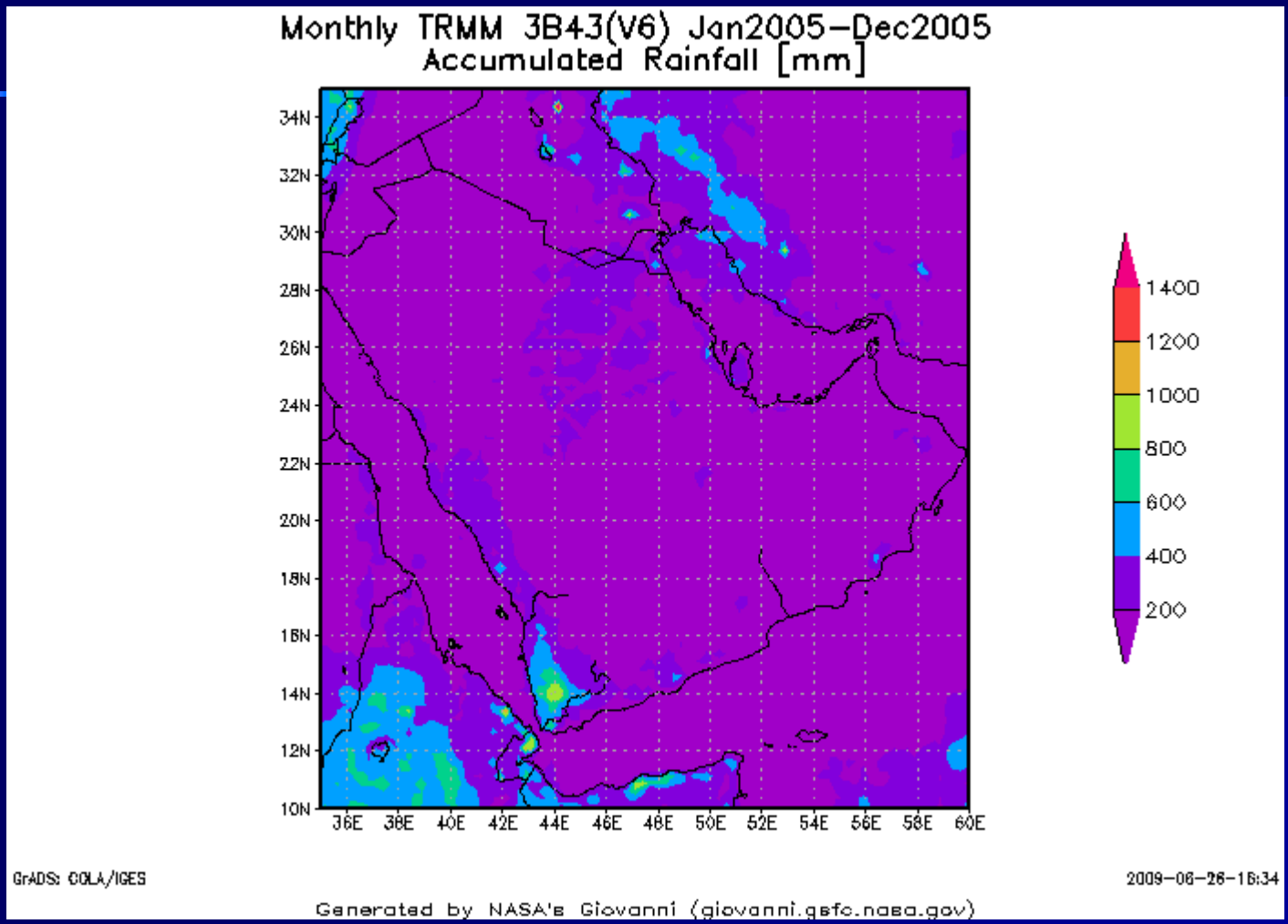
Monthly TRMM 3B43(V6) Jan2005–Dec2005
Accumulated Rainfall [mm]
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32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
1400
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600
400
200
GrADS: COLA/IGES
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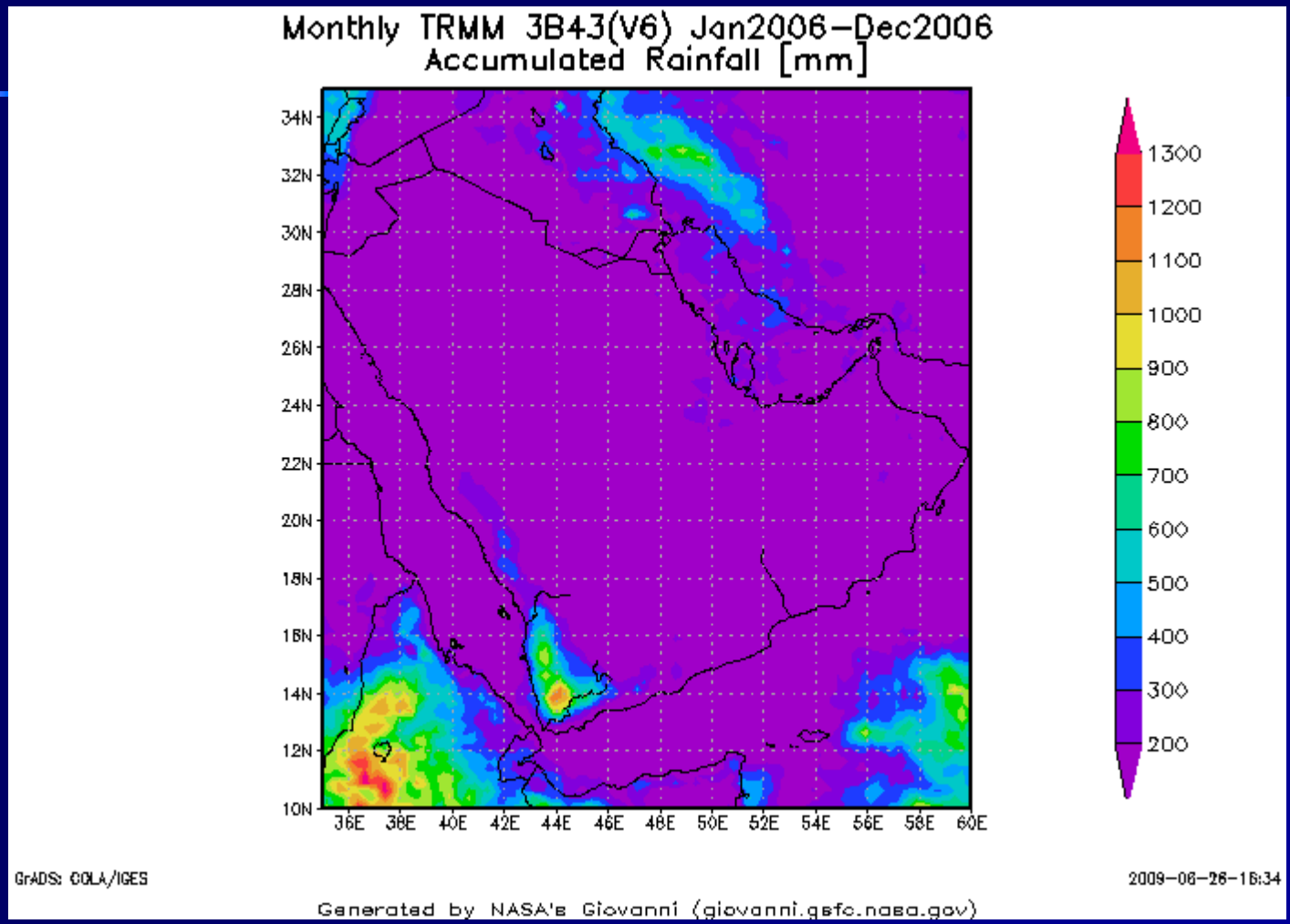
Monthly TRMM 3B43(V6) Jan2006–Dec2006
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
58E
60E
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1000
900
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700
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400
300
200
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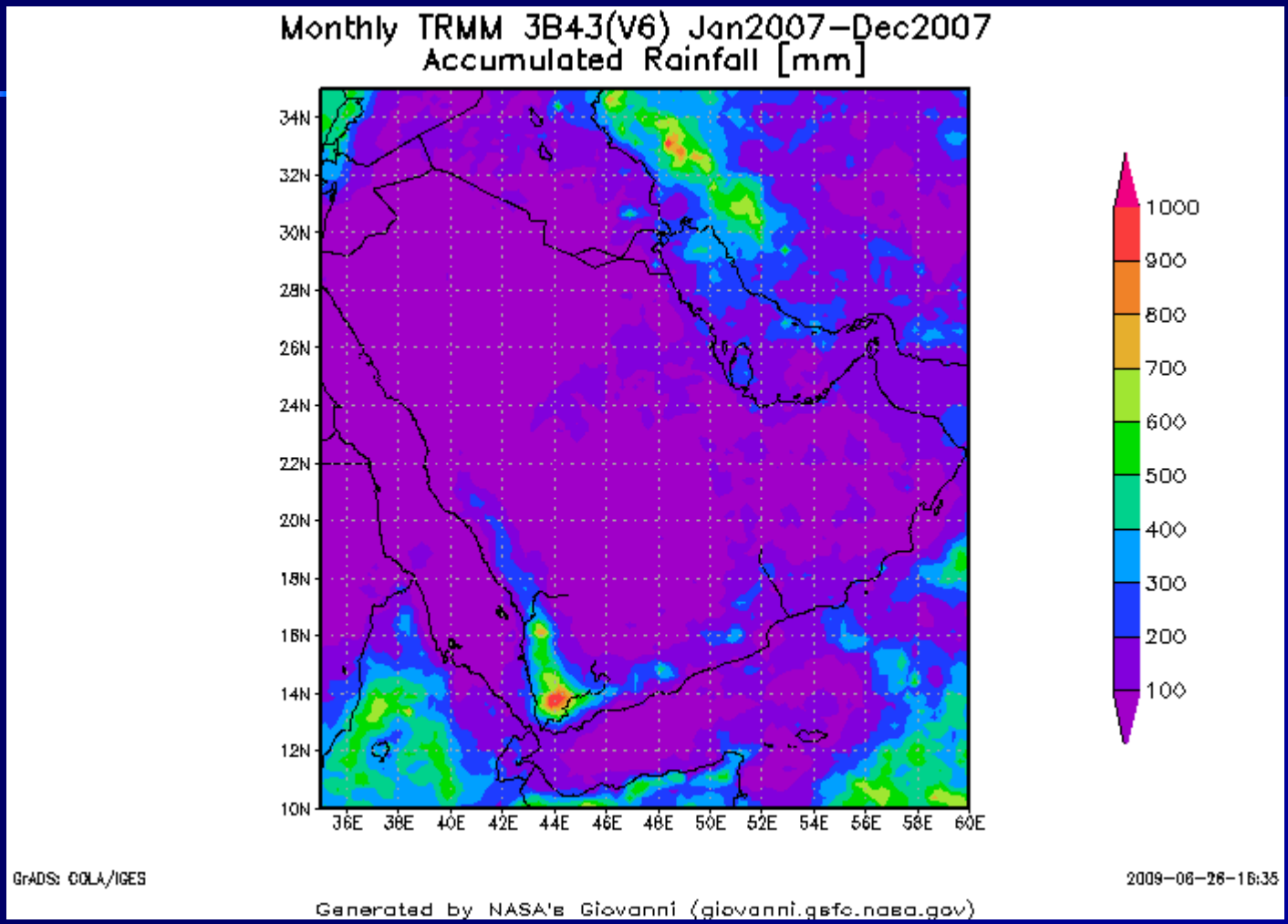
Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)


Monthly TRMM 3B43(V6) Jan2007–Dec2007
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
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800
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400
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200
100
GrADS: COLA/IGES
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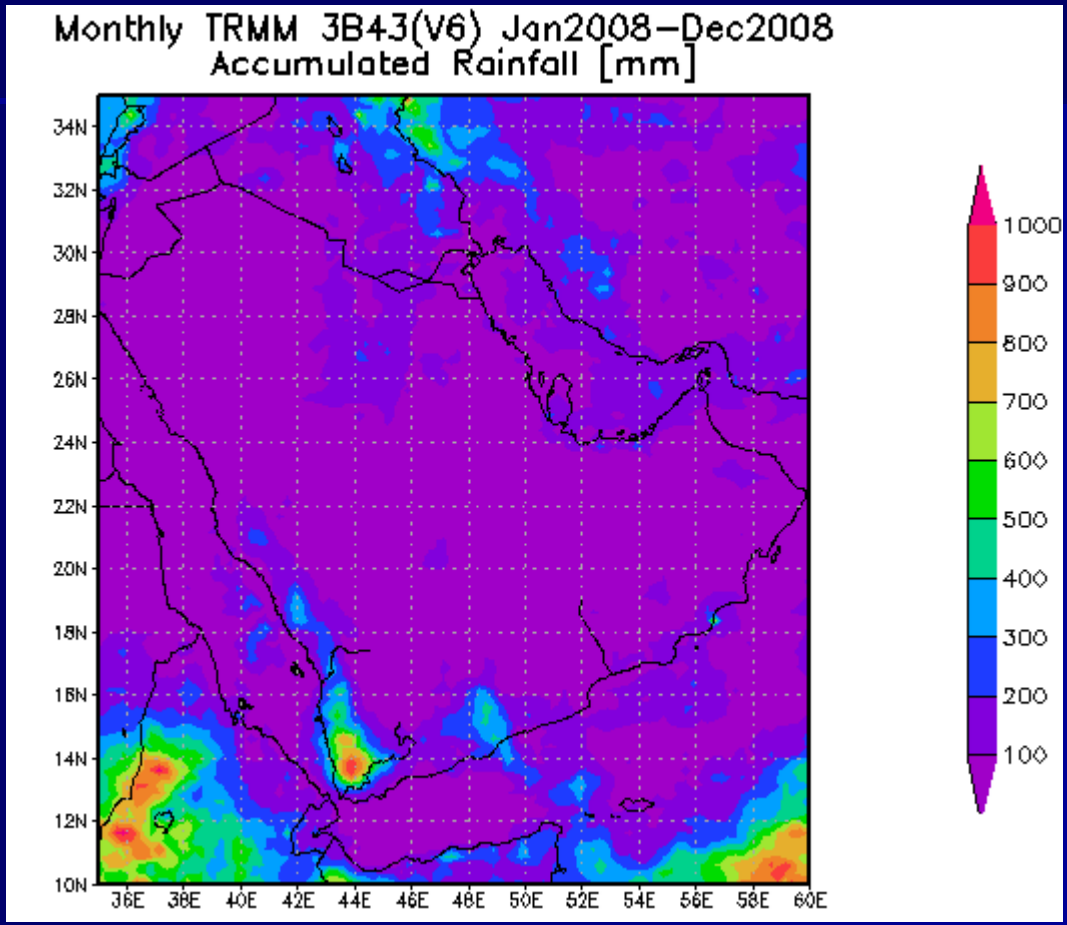
Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)


Monthly TRMM 3B43(V6) Jan2008–Dec2008
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
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1000
900
800
700
600
500
400
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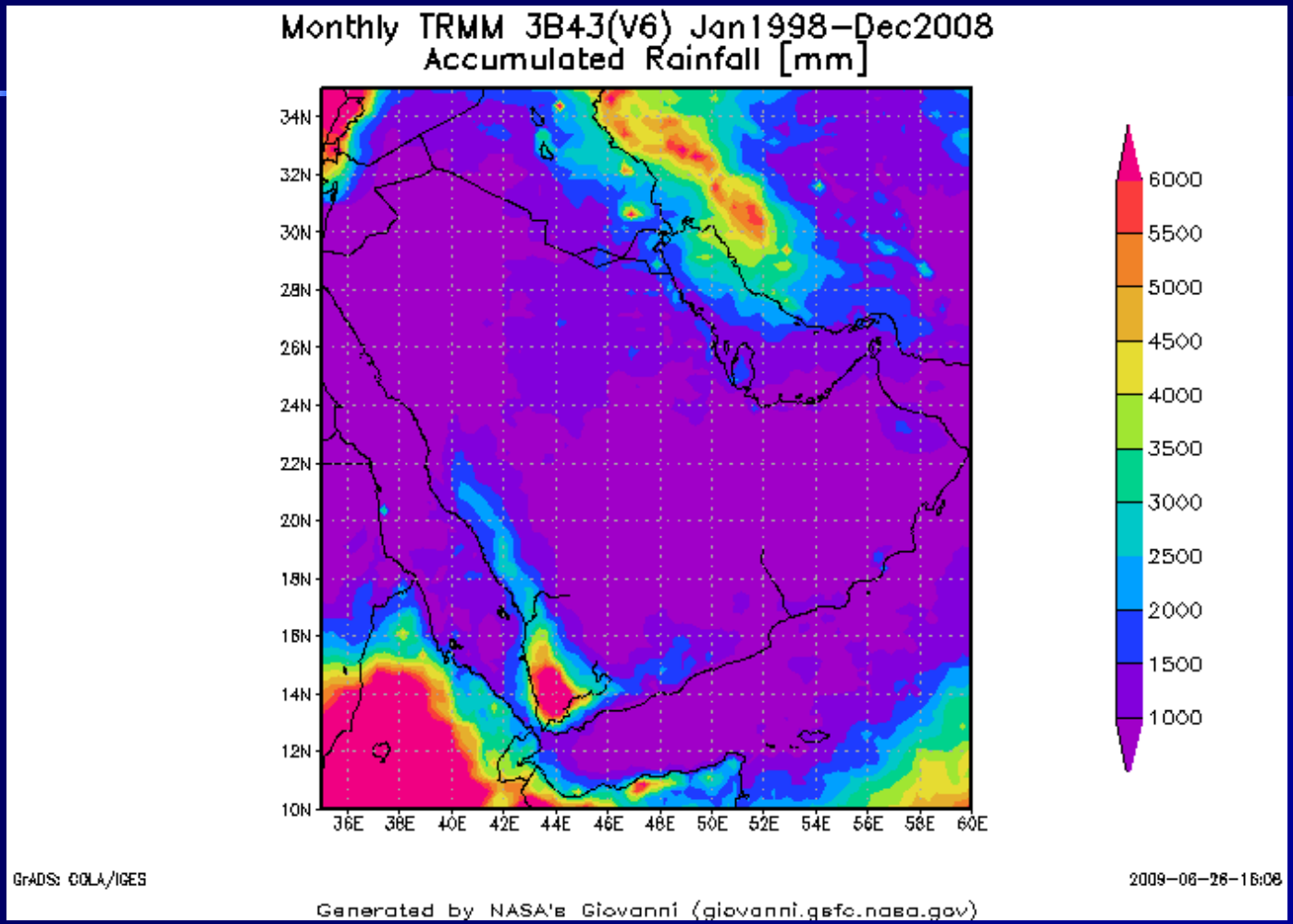
200
100


Monthly TRMM 3B43(V6) Jan1998–Dec2008
Accumulated Rainfall [mm]
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
36E
38E
40E
42E
44E
46E
48E
50E
52E
54E
56E
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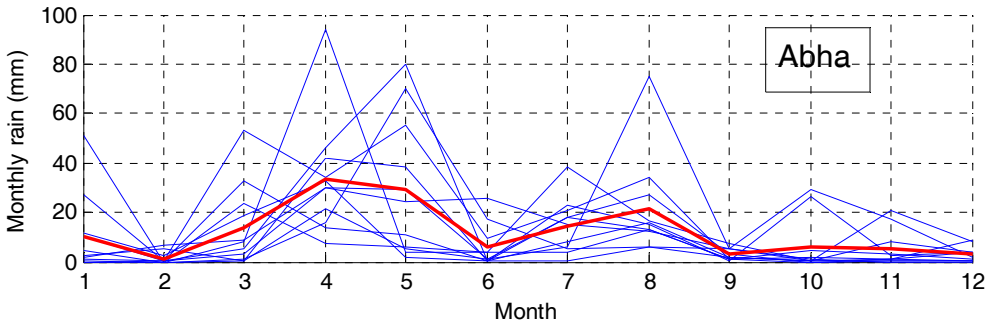
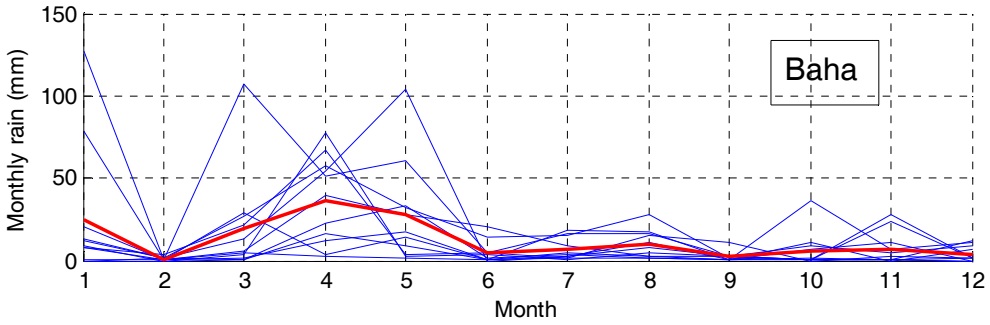
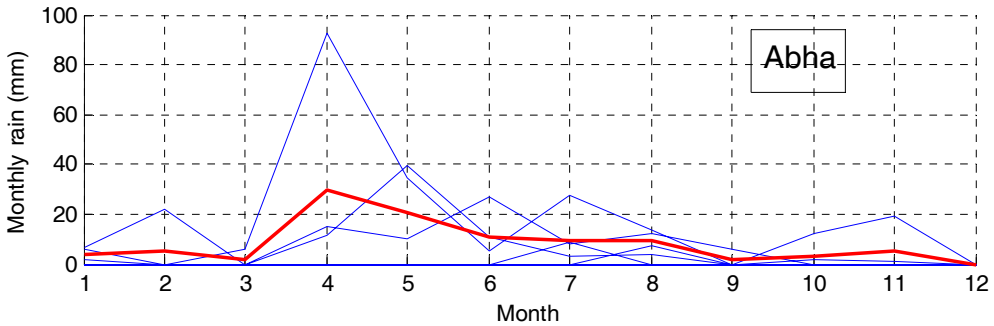
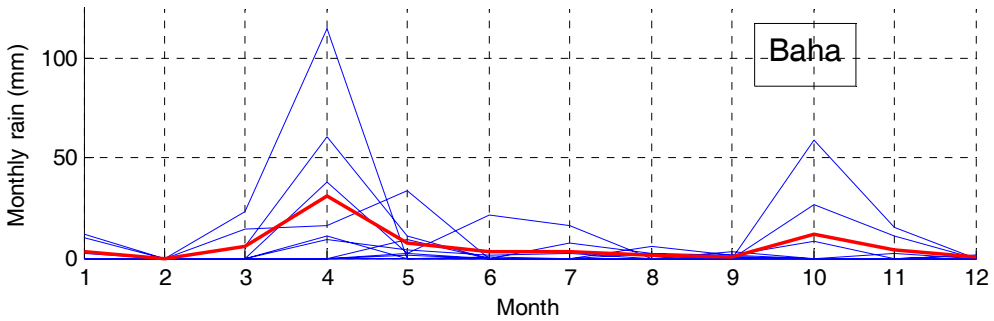
Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)

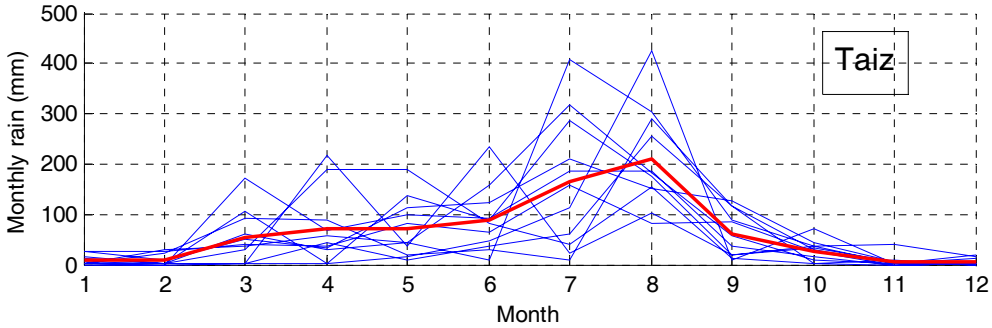


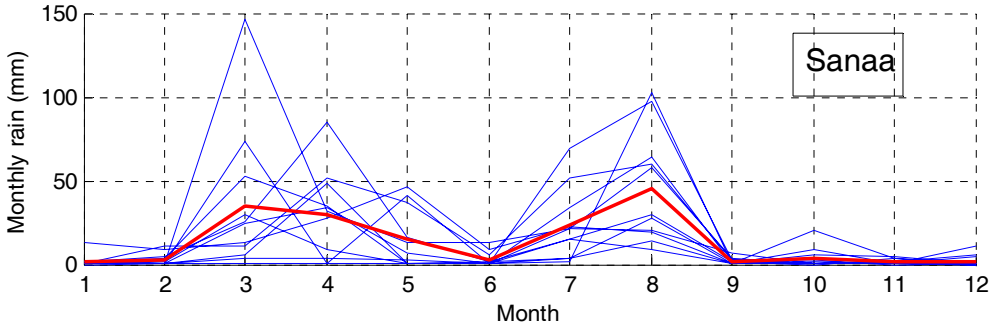


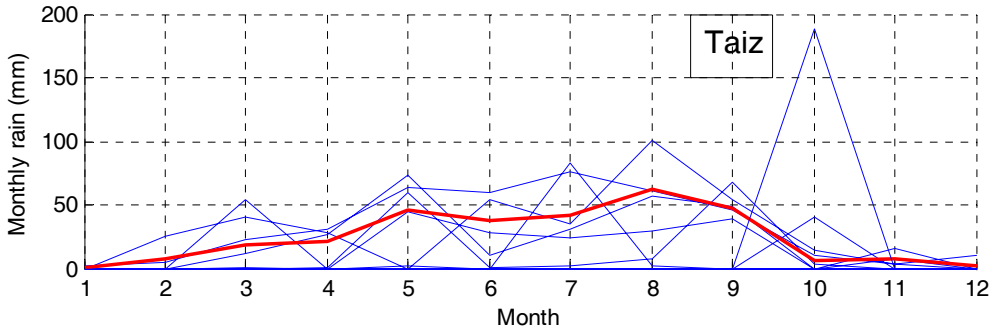


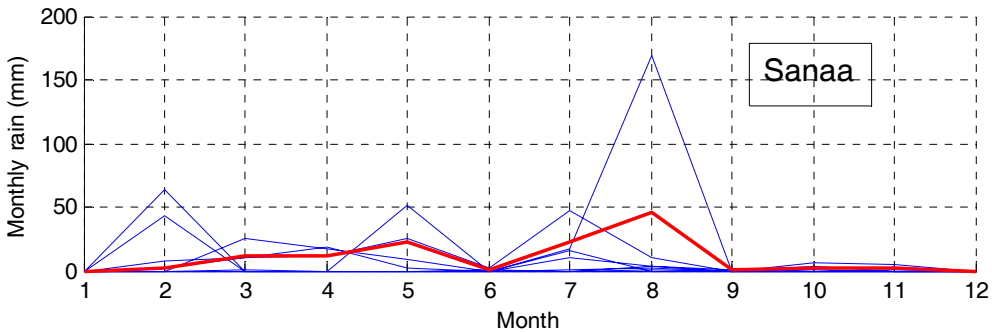


Comparison of rainfall seasonal cycle based on TRMM-TMPA dataset (upper two panels) and gauge observations (two lower panels) over two stations in Saudi Arabia

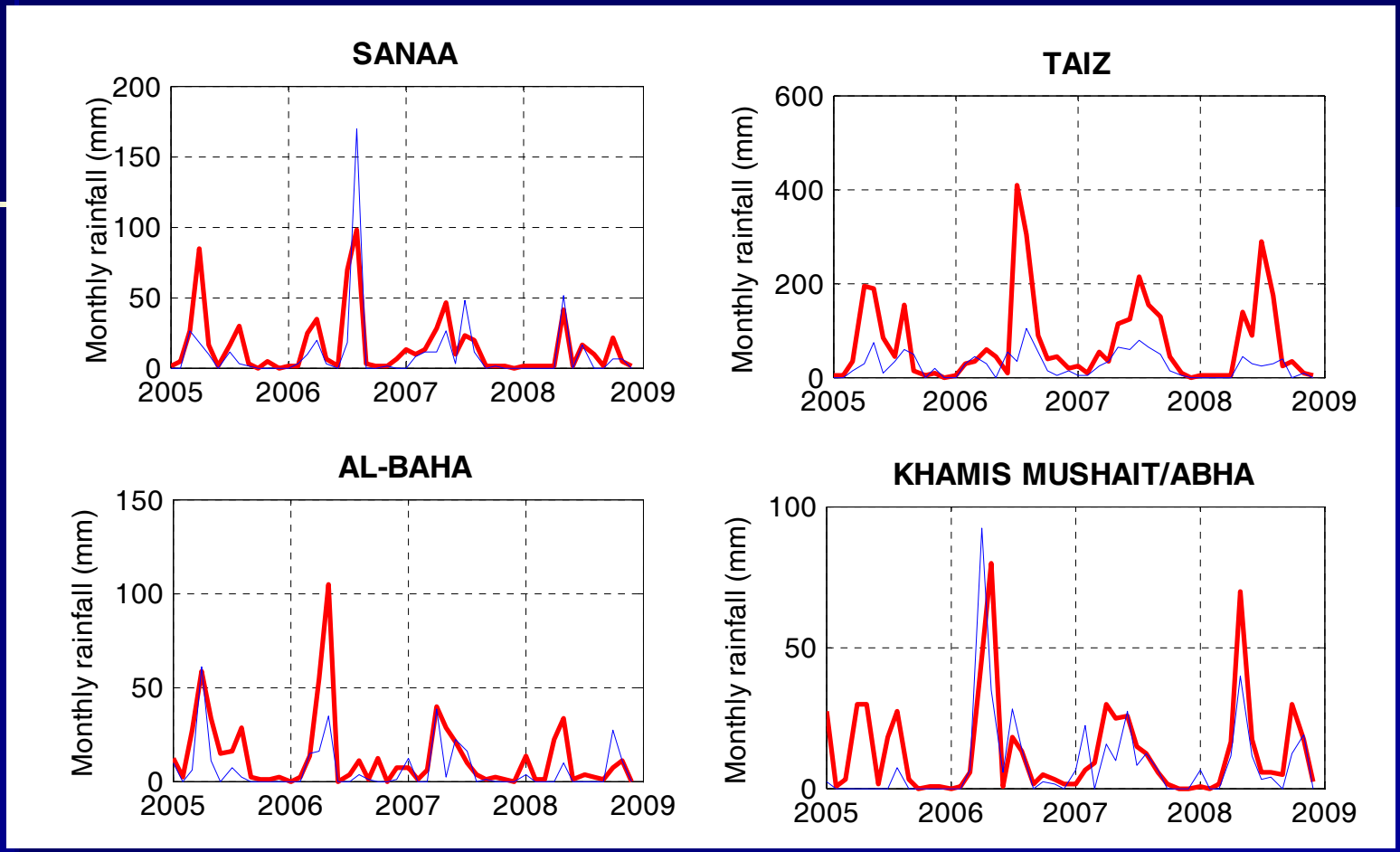




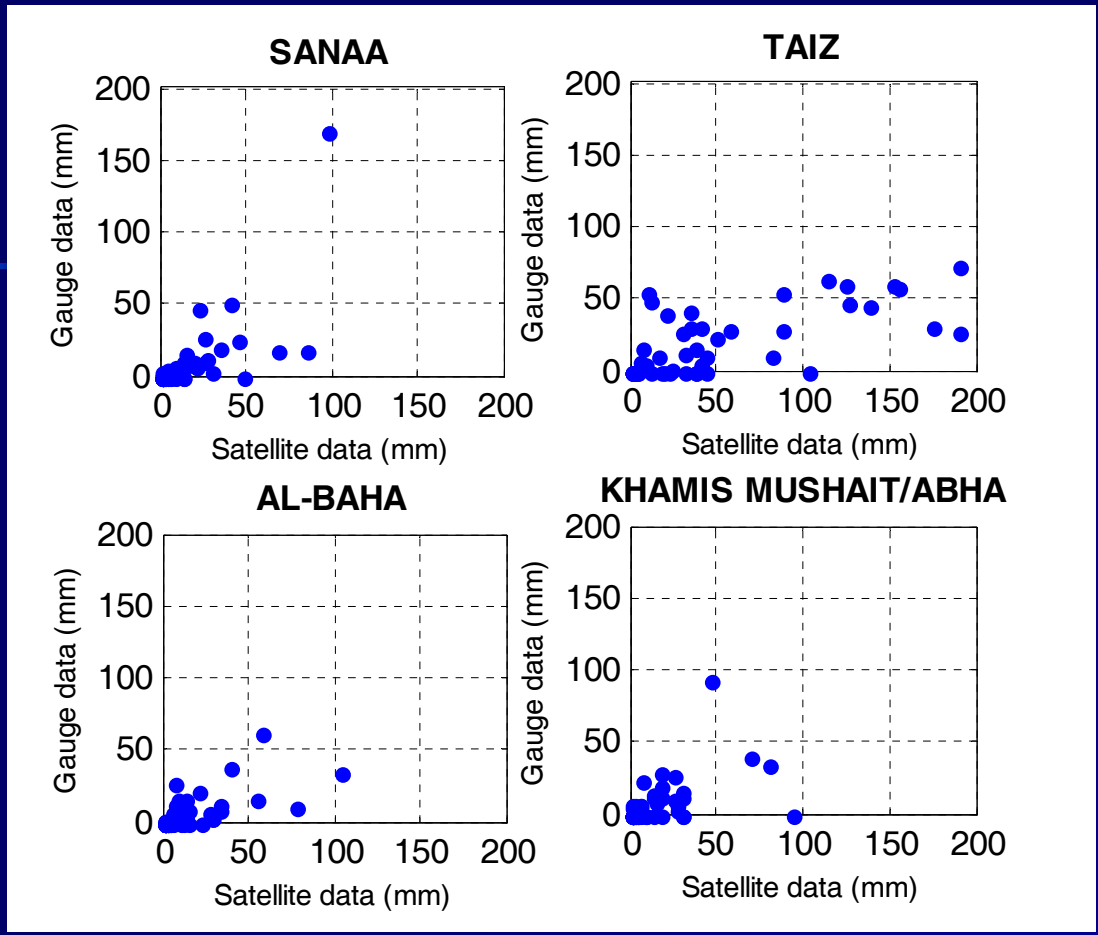




Comparison of rainfall seasonal cycle based on TRMM-TMPA dataset (upper two panels) and gauge observations (two lower panels) over two stations in Yemen



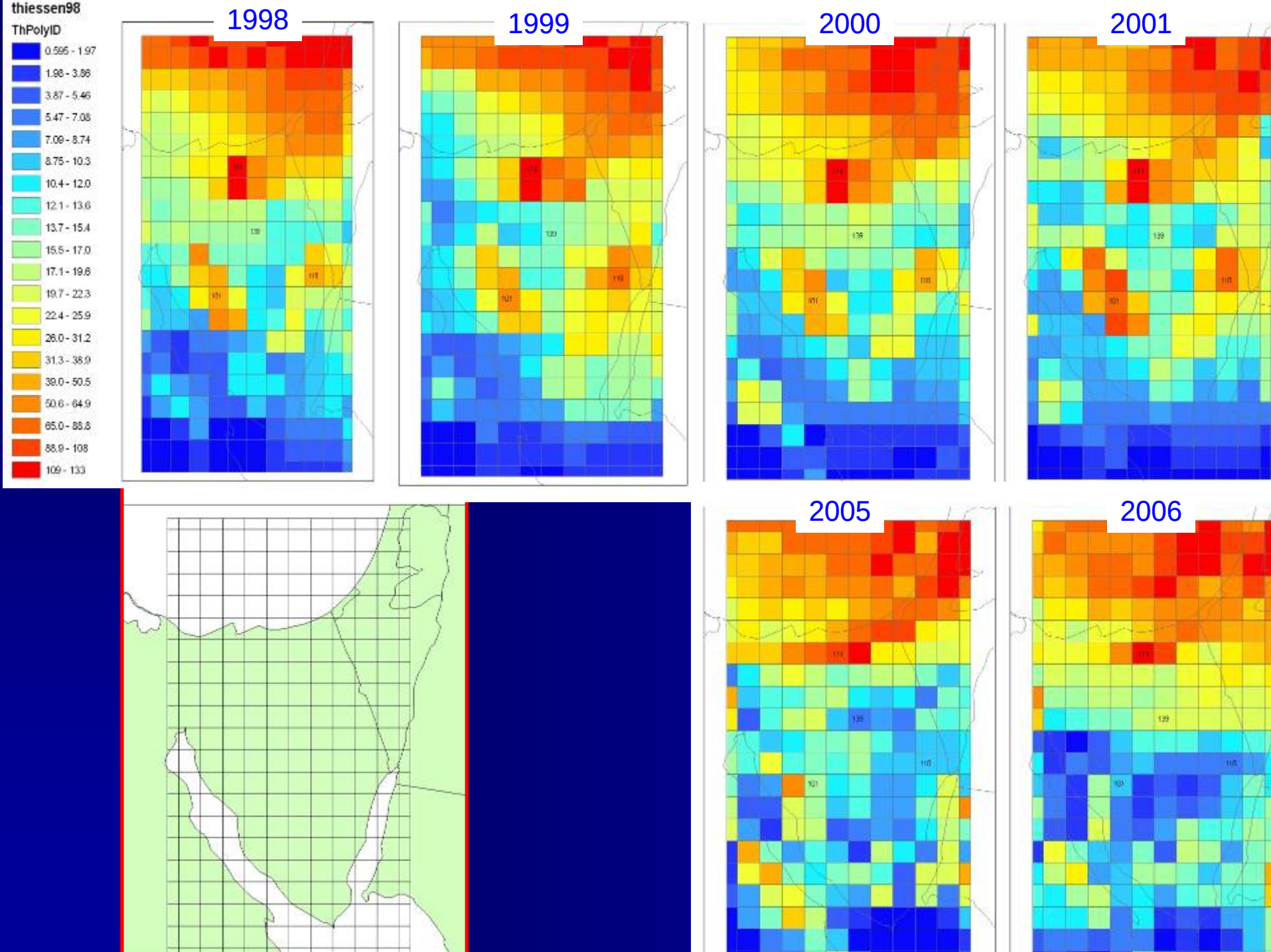
- Monthly rainfall from TRMM-TMPA satellite estimates versus the corresponding monthly rain gauge observations over four stations in Saudi Arabia and Yemen.

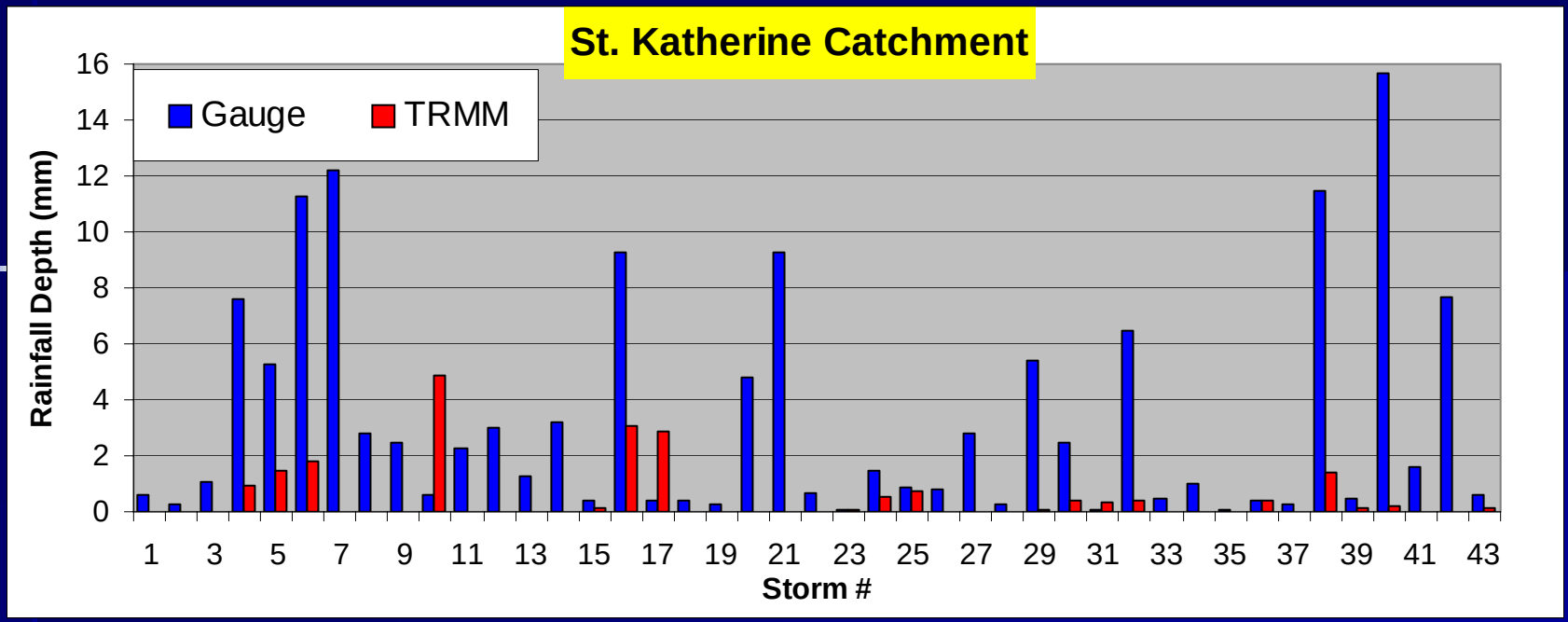


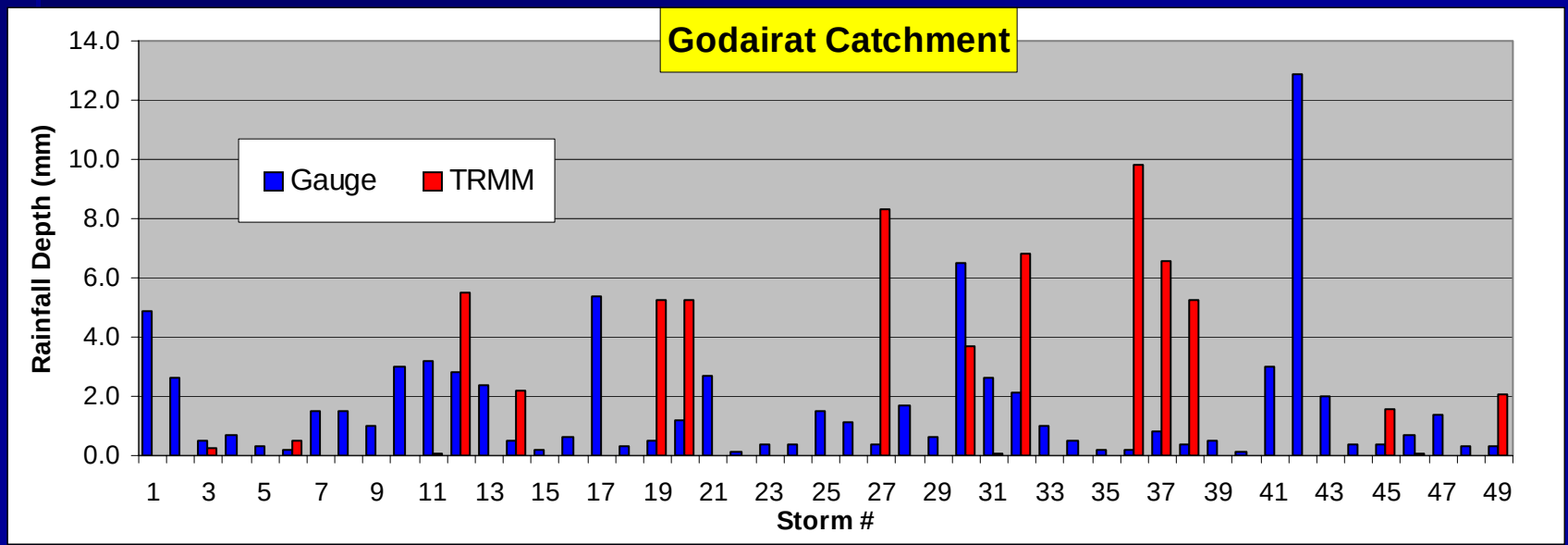
Scatter plot comparisons of monthly rainfall from TRMM-TMPA satellite estimates versus the corresponding monthly rain gauge observations over four stations in Saudi Arabia and Yemen.

Statistical Assessment

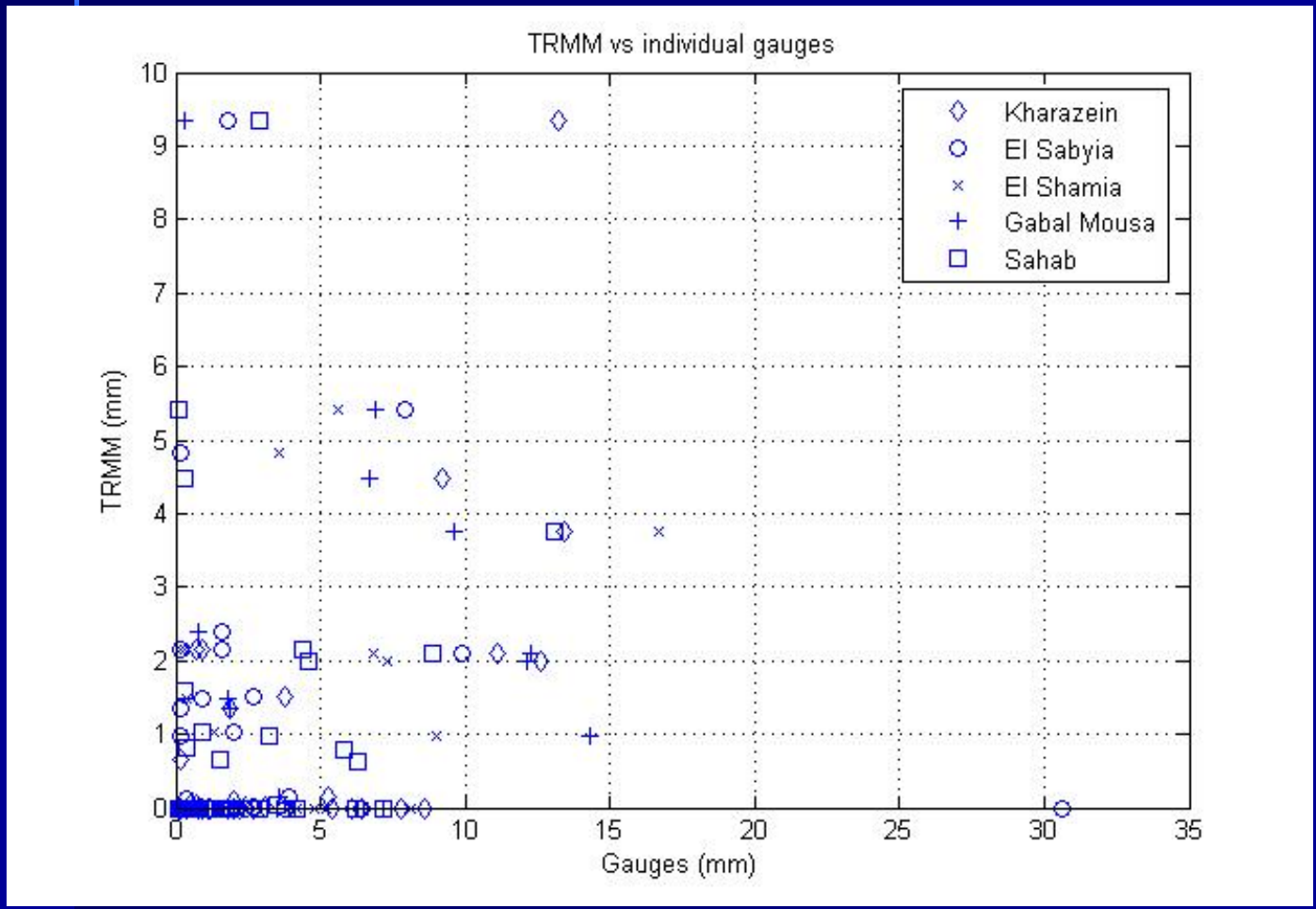
	TAIZ	SANAA	ABHA	AL-BAHA
Correlation Coefficient	0.56	0.71	0.52	0.67
Mean Absolute Error (mm)	52.81	8.31	8.93	8.05
Bias (ratio)	3.46	1.59	1.86	2.21


thiessen98
ThPolyID
0.596 - 1.97
1.98 - 3.86
3.87 - 5.46
5.47 - 7.08
7.09 - 8.74
8.75 - 10.3
10.4 - 12.0
12.1 - 13.6
13.7 - 15.4
15.5 - 17.0
17.1 - 19.6
19.7 - 22.3
22.4 - 25.9
26.0 - 31.2
31.3 - 38.9
39.0 - 50.5
50.6 - 64.9
65.0 - 88.8
88.9 - 108
109 - 133
1998
1999
2000
2001
2005
2006

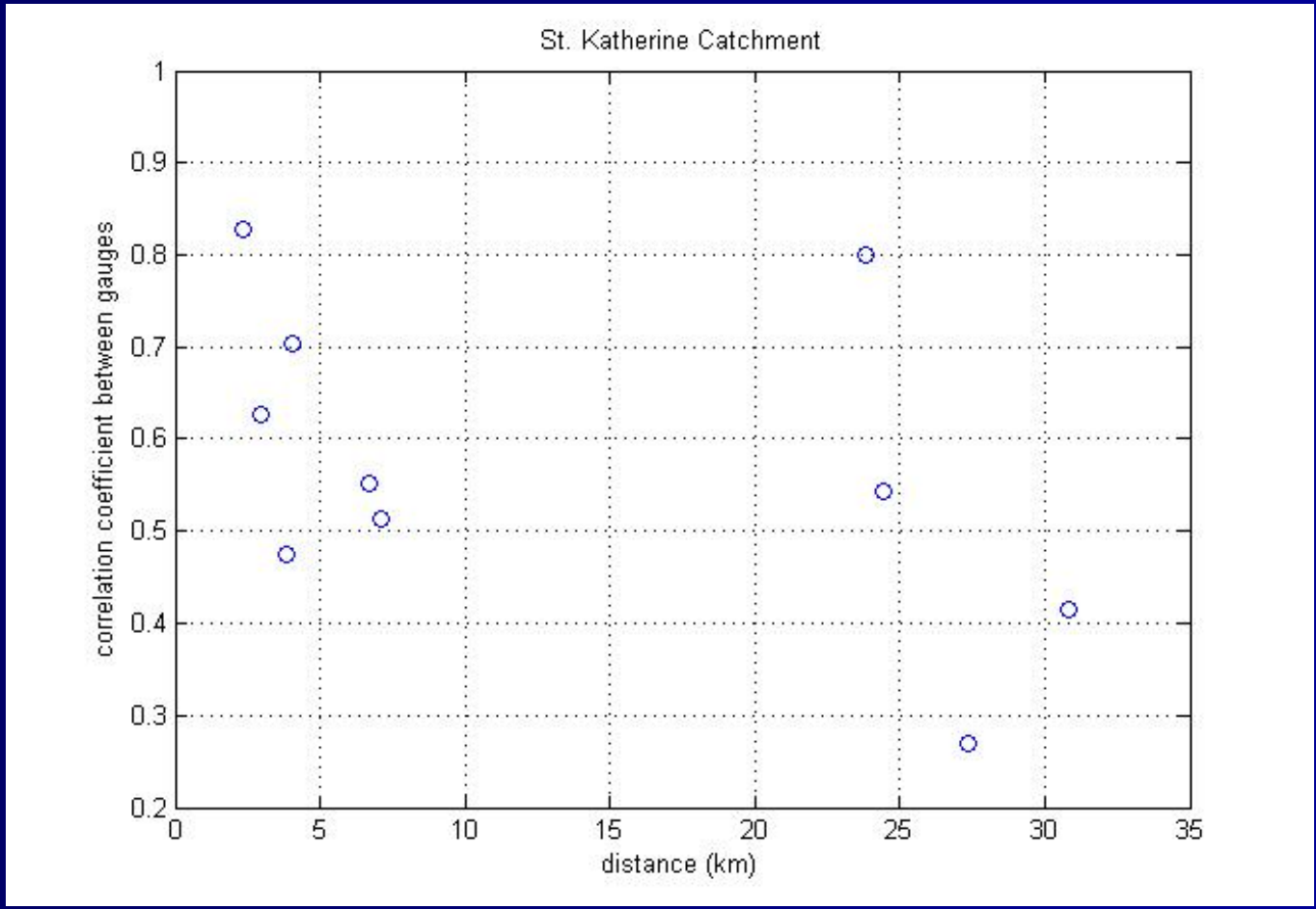

St. Katherine Catchment
Gauge
TRMM
Rainfall Depth (mm)
0
2
4
6
8
10
12
14
16
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43
Storm #


Godairat Catchment
Gauge
TRMM
Rainfall Depth (mm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Storm #

St. Catherine catchment; Sinai



Gauges Issues



Summary & Conclusions

- Satellite estimates are showing much wetter Sinai than expected
  - more evident over land more than over water
  - “desert artifacts” with unrealistically high rainfall
  - occurring more during cold-temperature hours/days
- Seasonal patterns were mostly similar to those from gauges.
- Statistical analysis shows reasonable agreement in timing and detection
- However, considerable differences were reported in bias and mean absolute errors.
- Such differences could be attributed to algorithmic problems; but also to the low quality of rain gauges.

Concluding remarks

- Satellites provide viable rainfall information in un-gauged regions
  - global coverage
  - Relatively high temporal resolution
- High potential for hydrologic applications
- Satellites don't measure rainfall directly:
  - Estimation
  - Validation (Uncertainty Analysis)
- We need surface observations ("ground truth")
  - Limited number and records of rain gauges in arid regio
  - Establish experimental rain gauge sites.

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