



Does the driest part of the Sahara Desert have a rainy season?

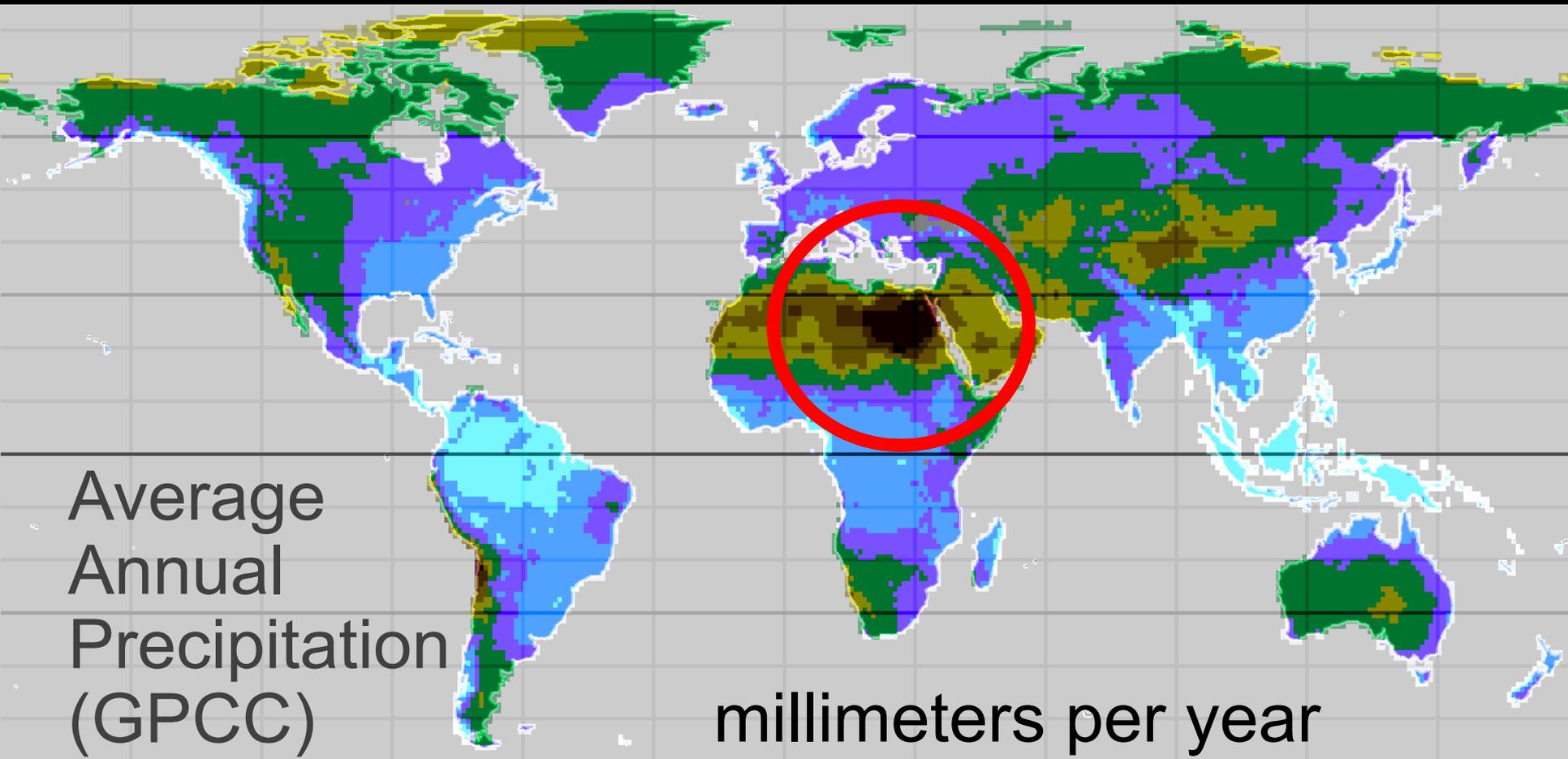
Owen Kelley

George Mason University and NASA Goddard

30 October 2014

Brown Bag Seminar, NOAA Central Library

A "hole" in Earth's climate



Average
Annual
Precipitation
(GPCC)

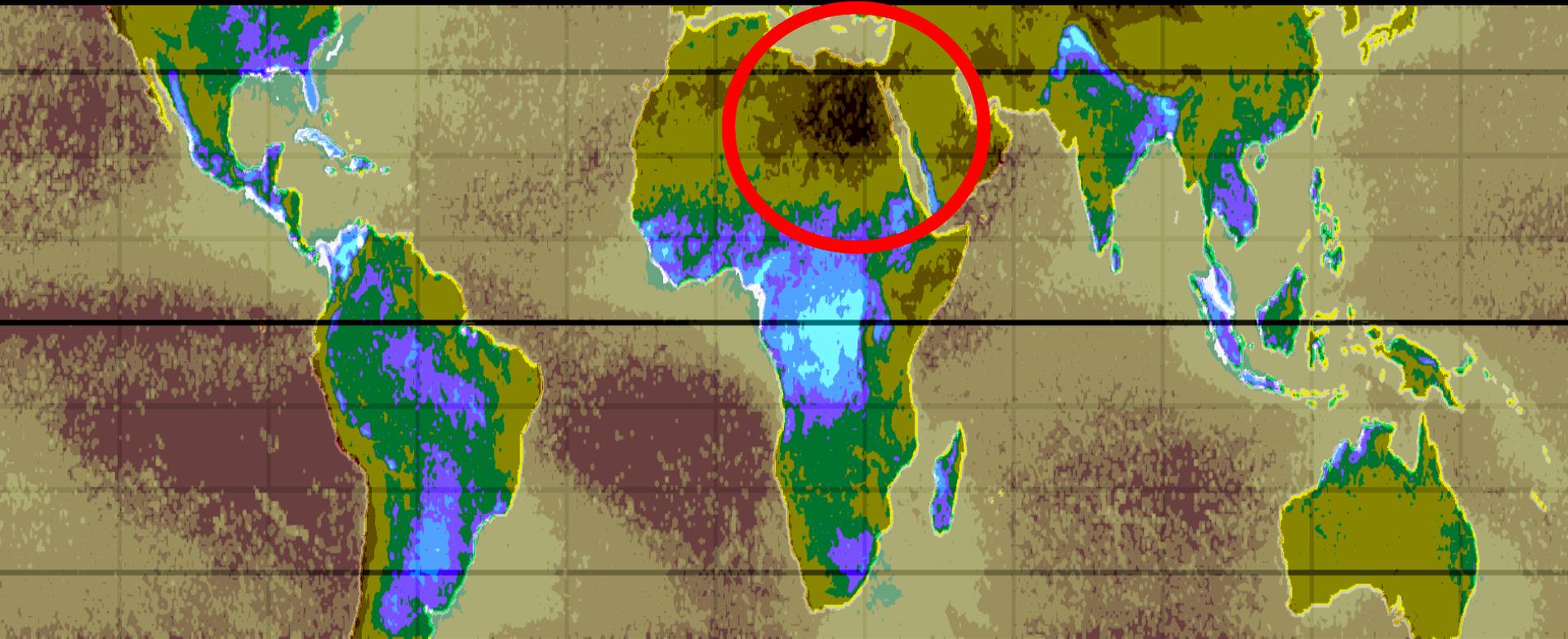
millimeters per year

0 5 15 50 150 500 1000 2000



Data: GPCC version 7 full analysis, 1998-2012 (Becker et al. 2013), Image: Owen Kelley

A "hole" in Earth's climate

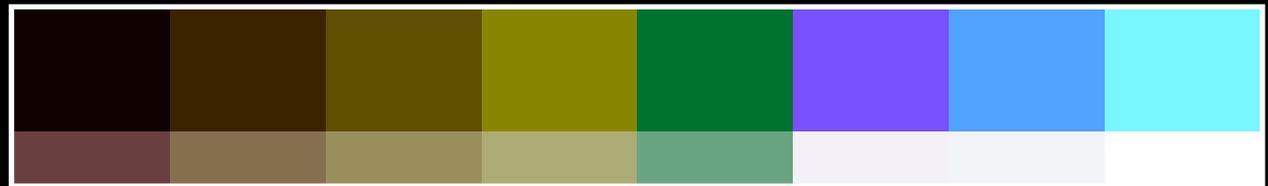


Annual-Average Lightning Flash Density (TRMM LIS)

0 0.01 0.1 1 10 20 30 50

flash
per km²
per year

Land
Ocean



[1]

The Three Mysteries

The Three Mysteries

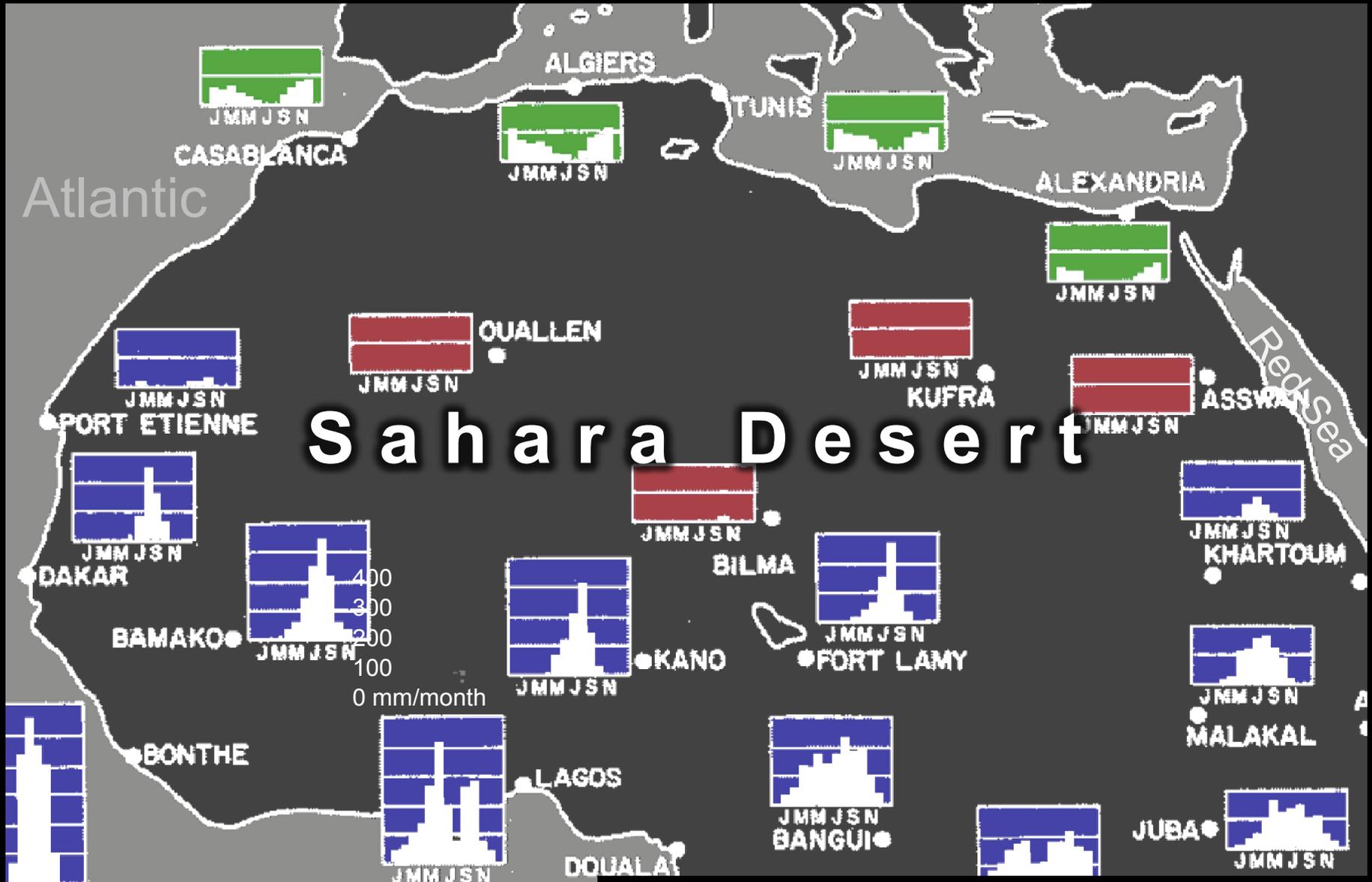
1. Which part of the Sahara receives the least rain?
2. On average, how much rain falls there each year?
3. Is there evidence of seasonal organization to this rainfall?

[2]

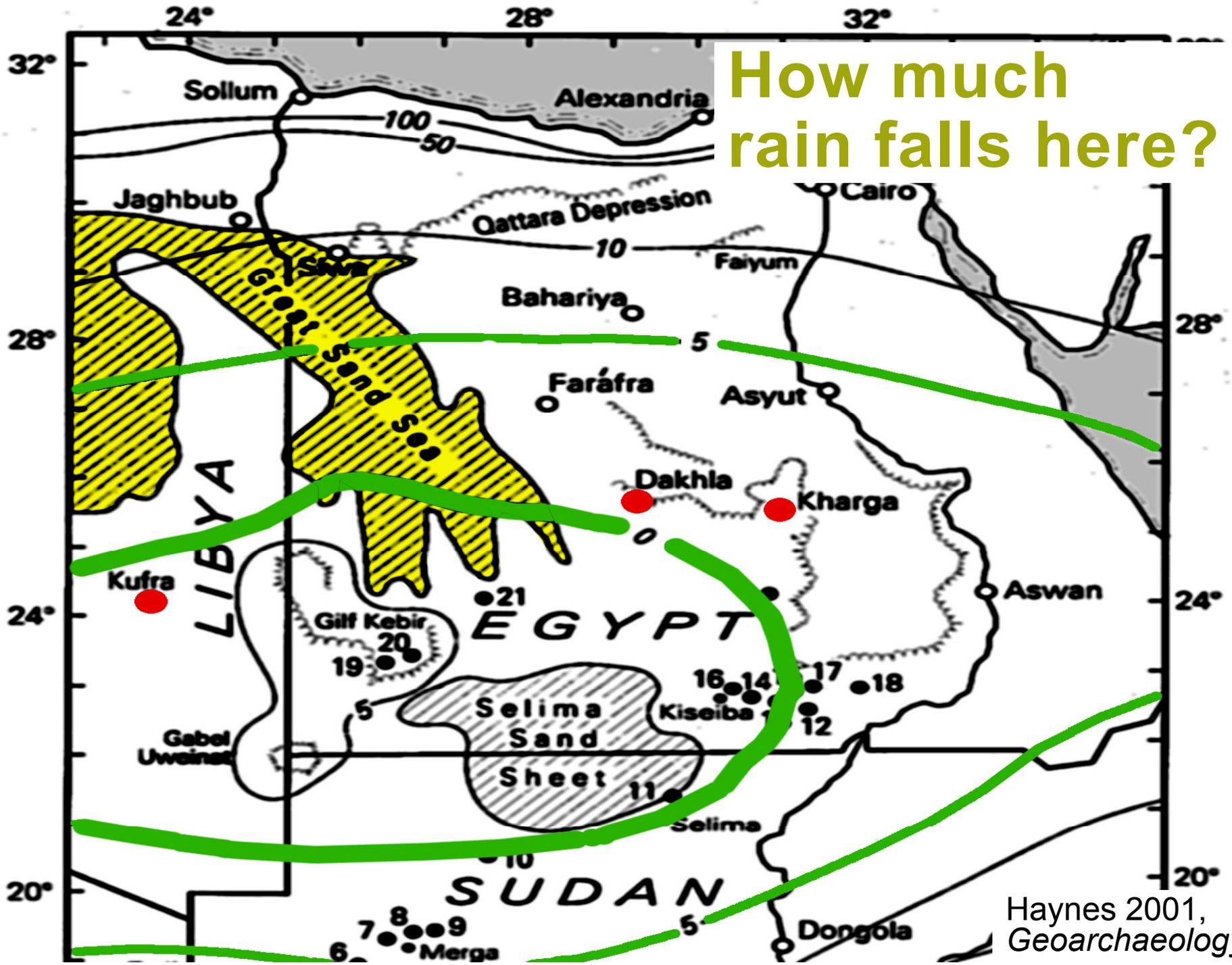
Where?

How much?

Where in the Sahara does the least rain fall?



How much rain falls here?



How much rain falls here?

The Study-Region



[3]

The Last Mystery

No rainy season? (1952)

Paraphrasing Peveril Meigs:

Extreme aridity means that a given locality has at least 12 consecutive months without rain recorded and there is **no regular seasonal rhythm of rainfall**.... The upper limit of rainfall in hot deserts... 65 mm.

Meigs classified basically all of the Sahara Desert as extremely arid.

Ea24 (extreme arid, no distinct season, average temperature of coldest and warmest months: 10-20C, >30C)

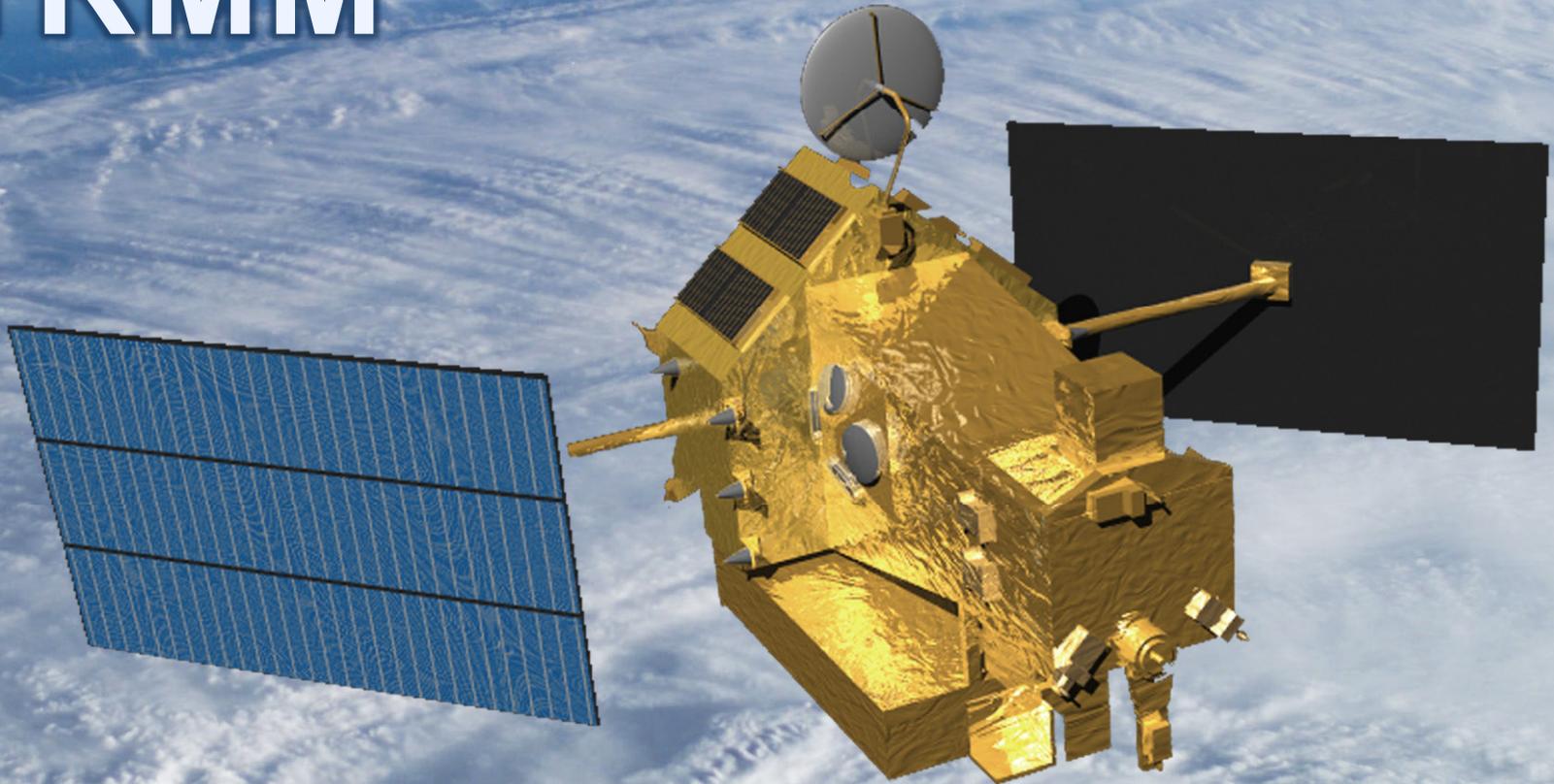
Two rainy seasons, but only at the desert's edge? (2006)

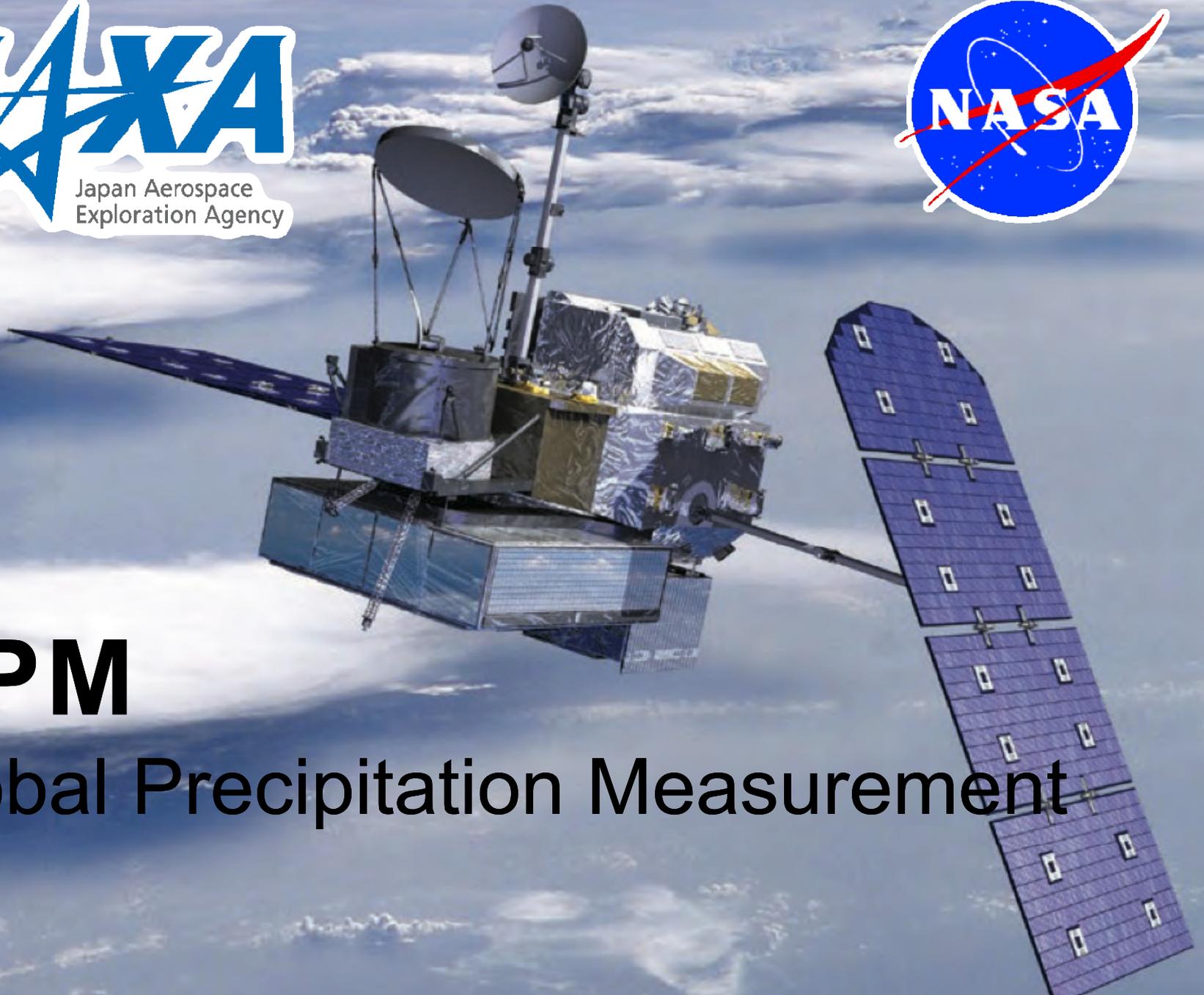
The UN's *Global Desert Outlook*:

The Sahara Desert... is dominated by winter rains in its northern Mediterranean **limit** and by summer rains in its more tropical Sahelian **border**.

The document's maps show the Sahara covering 15°-30°N in eastern Africa. The driest part of the Sahara covers only 20°-27°N.

Tropical Rainfall Measuring Mission TRMM



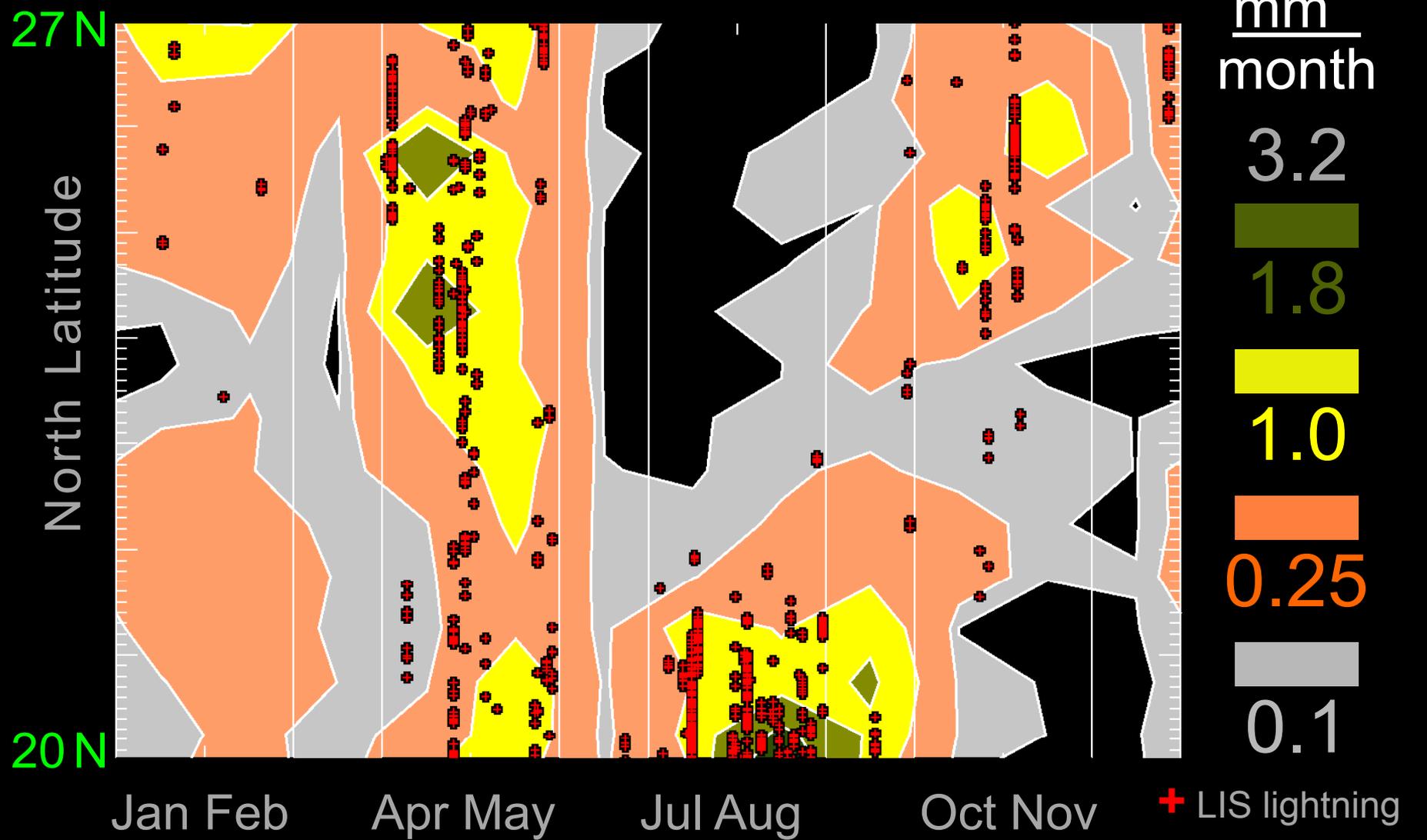


GPM

Global Precipitation Measurement

Avg. monthly rain, driest part of Sahara

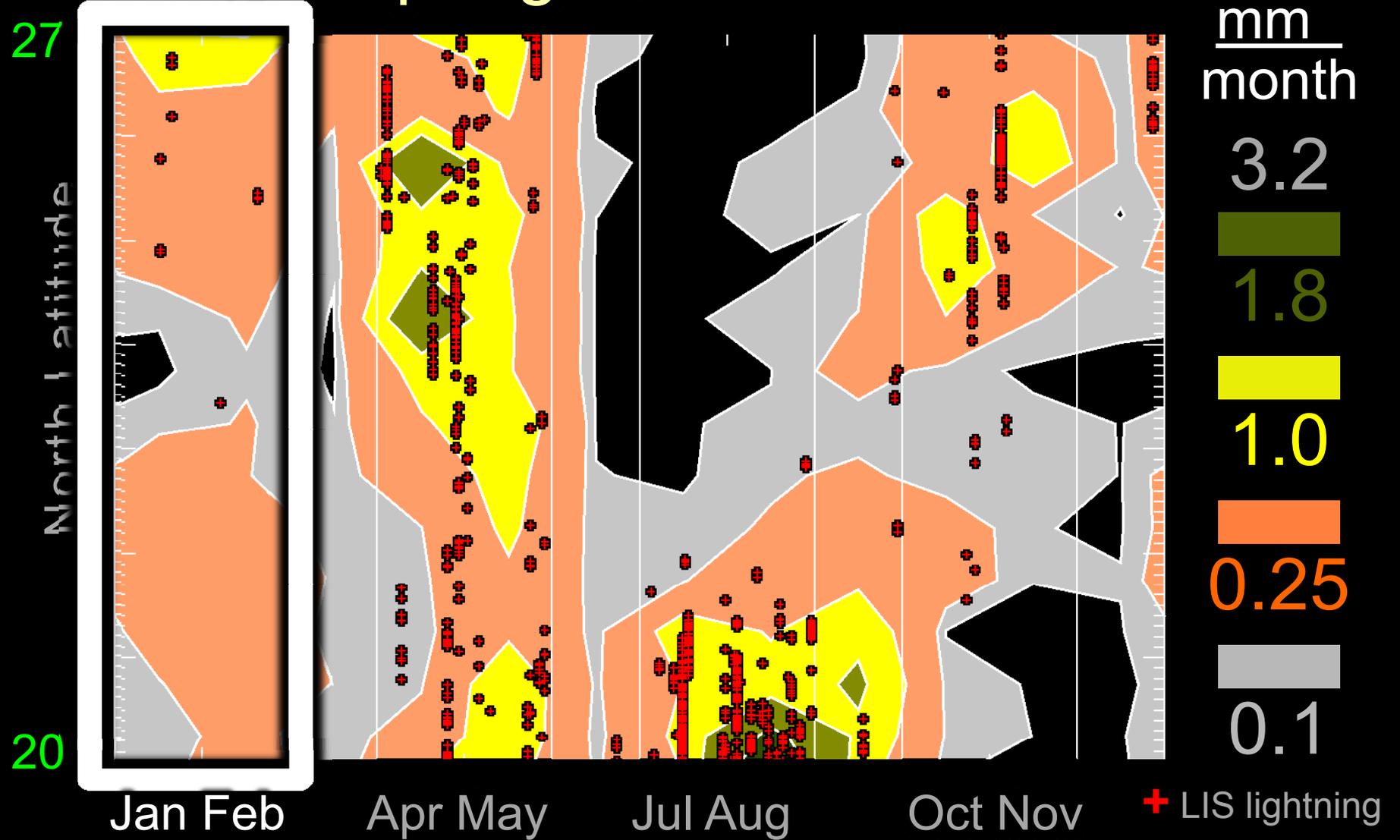
Winter Spring Summer Autumn



TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

Avg. monthly rain, driest part of Sahara

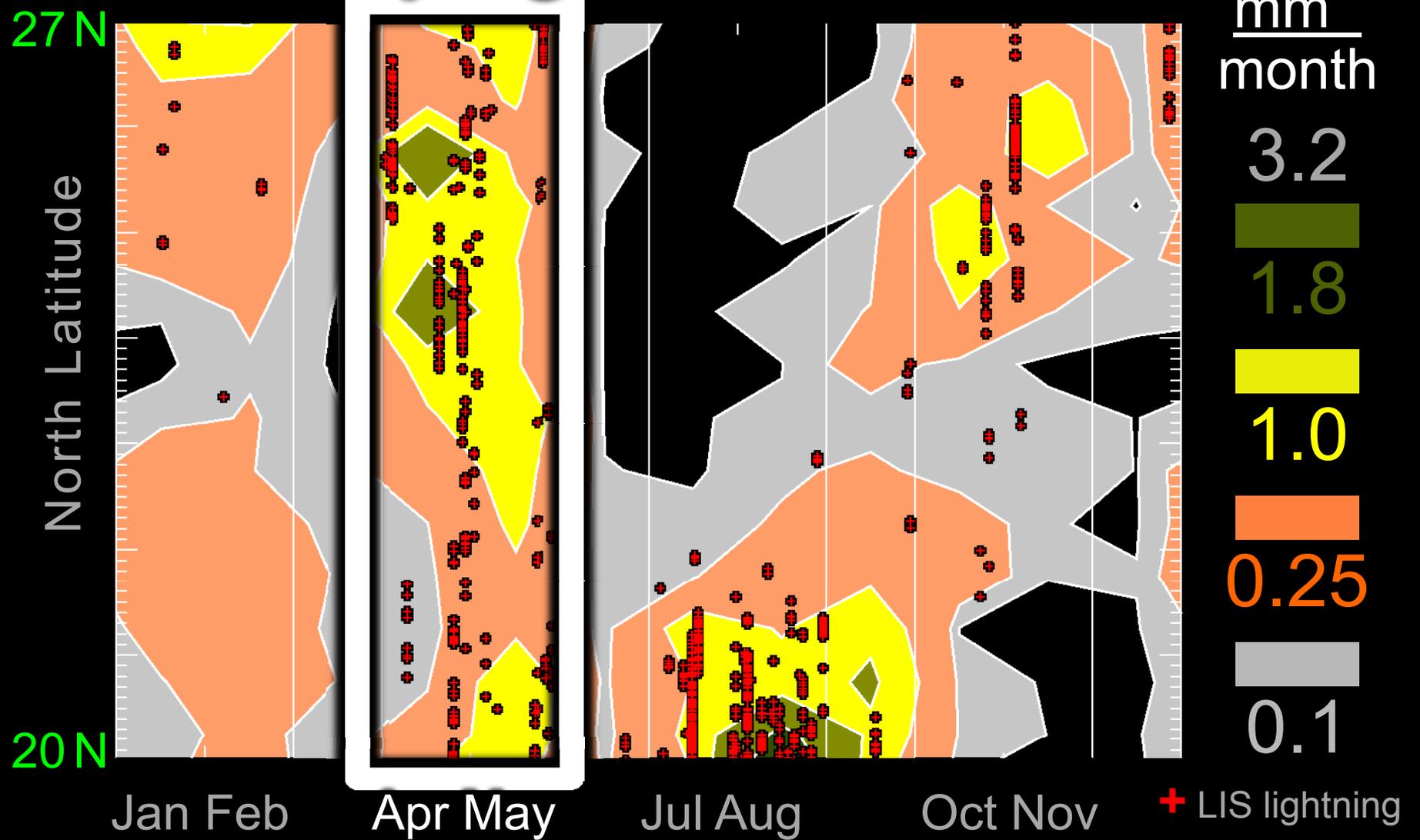
Winter Spring Summer Autumn TRMM Radar



TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

Avg. monthly rain, driest part of Sahara

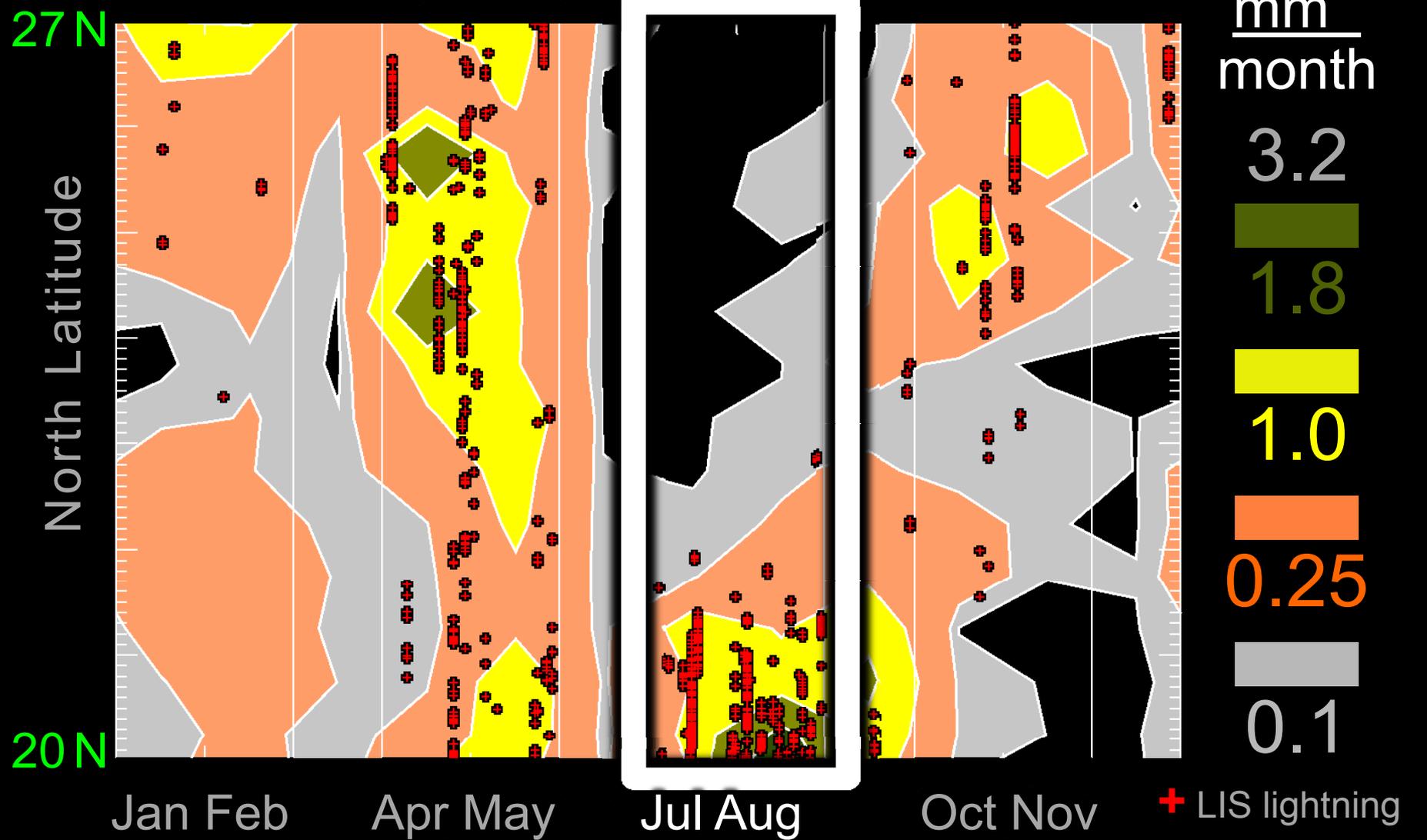
Winter **Spring** Summer Autumn TRMM Radar



TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

Avg. monthly rain, driest part of Sahara

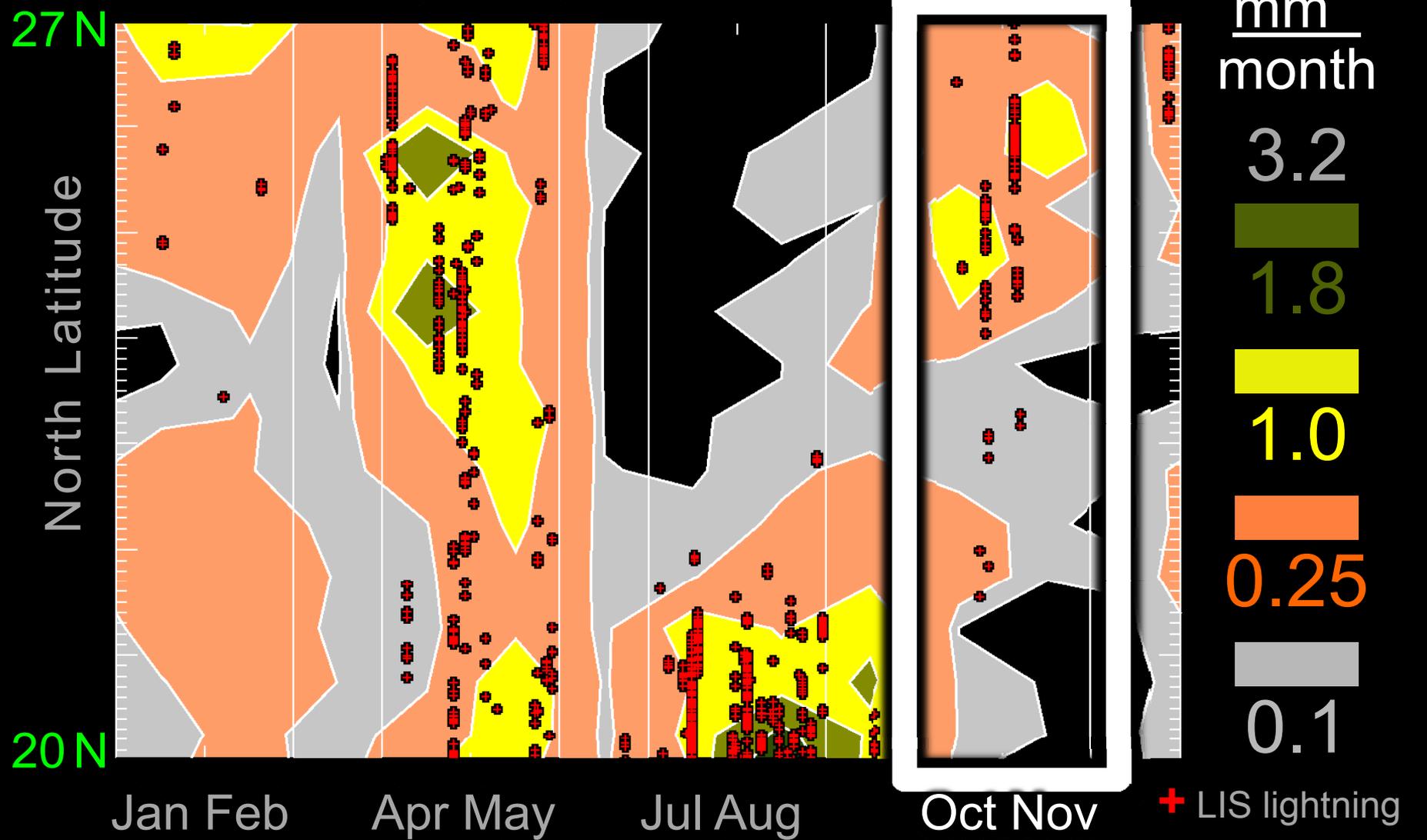
Winter Spring **Summer** Autumn TRMM Radar



TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

Avg. monthly rain, driest part of Sahara

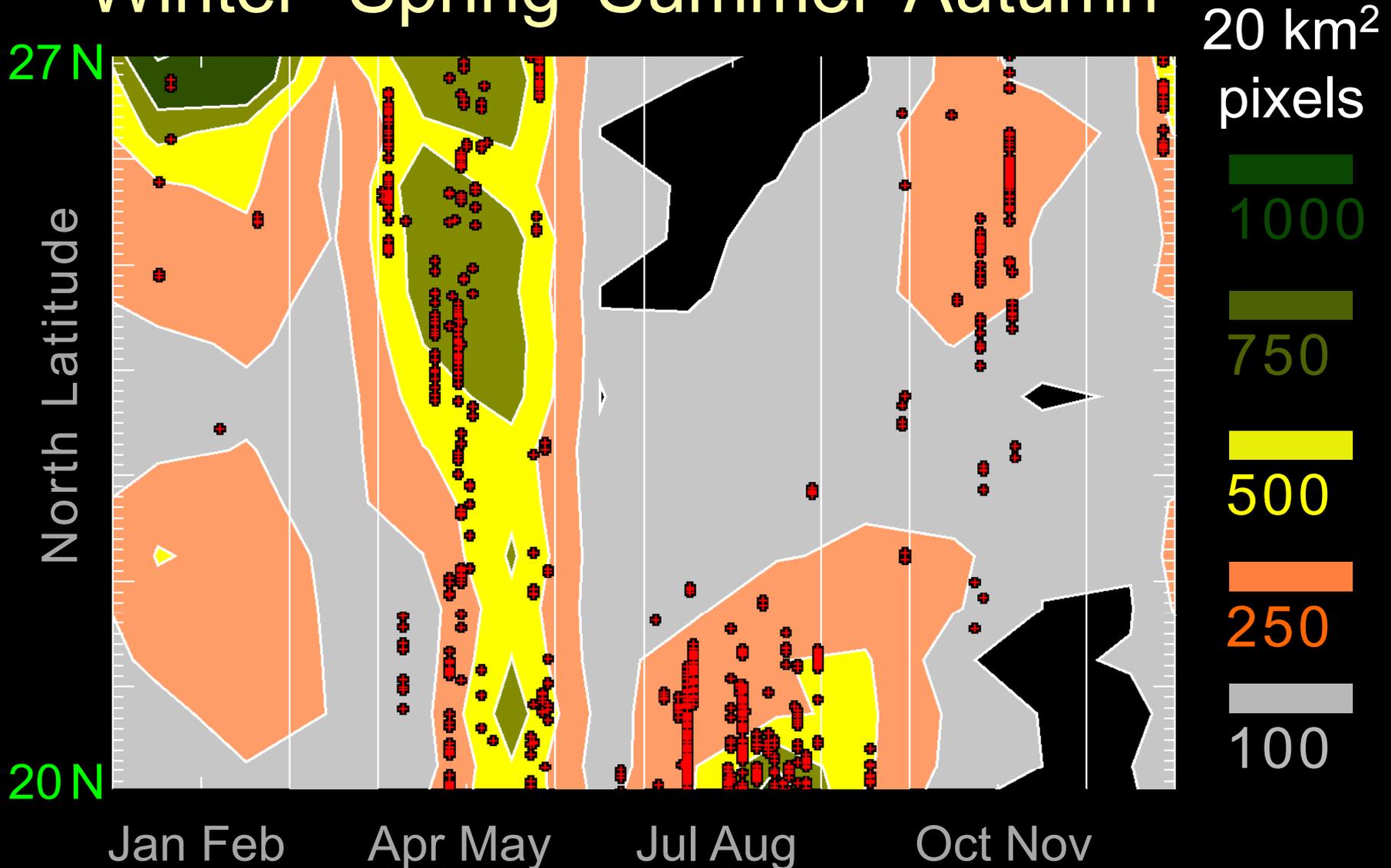
Winter Spring Summer **Autumn**



TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

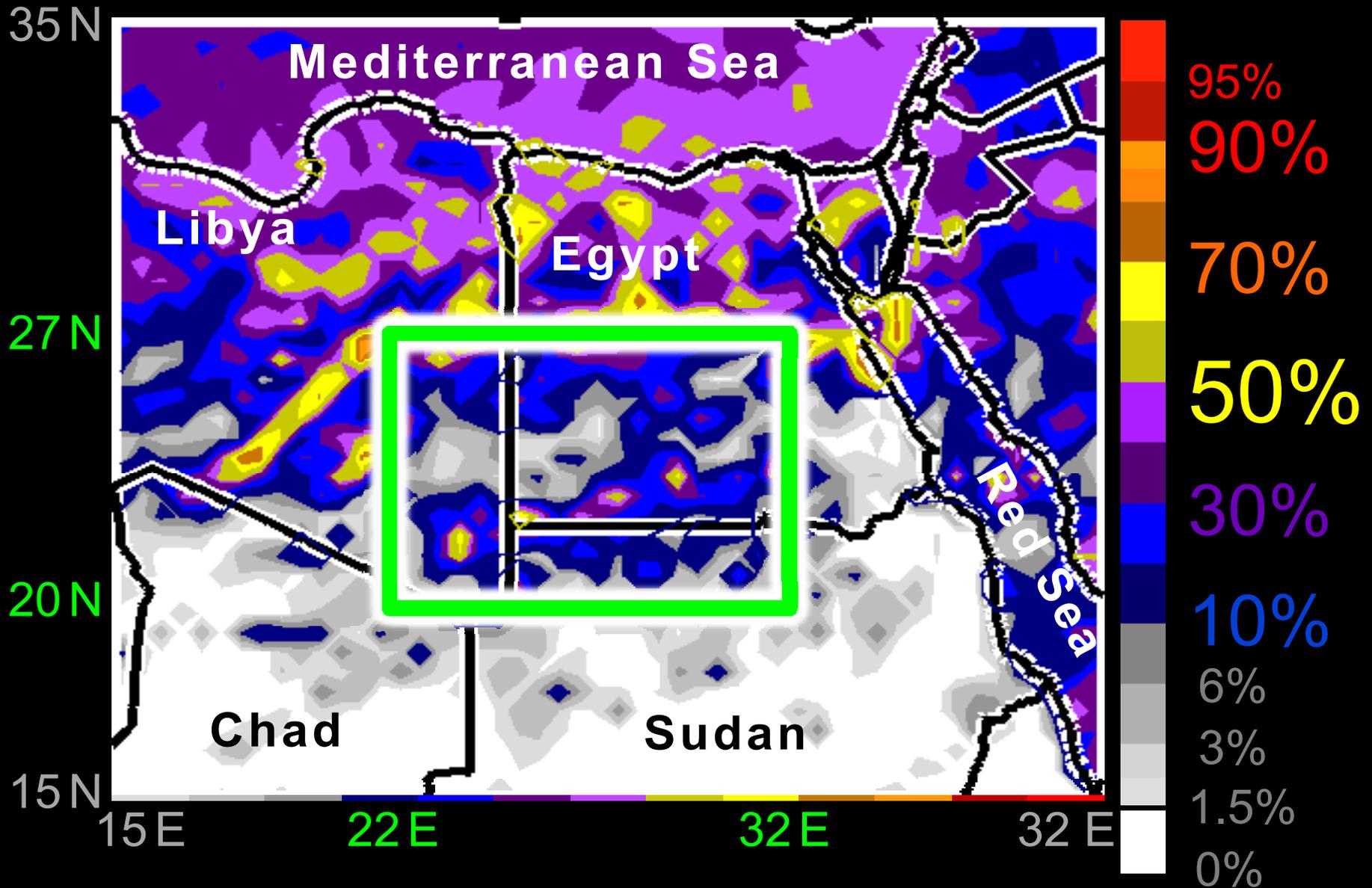
Number of rain observations per 0.5°Lat per month

Winter Spring Summer Autumn

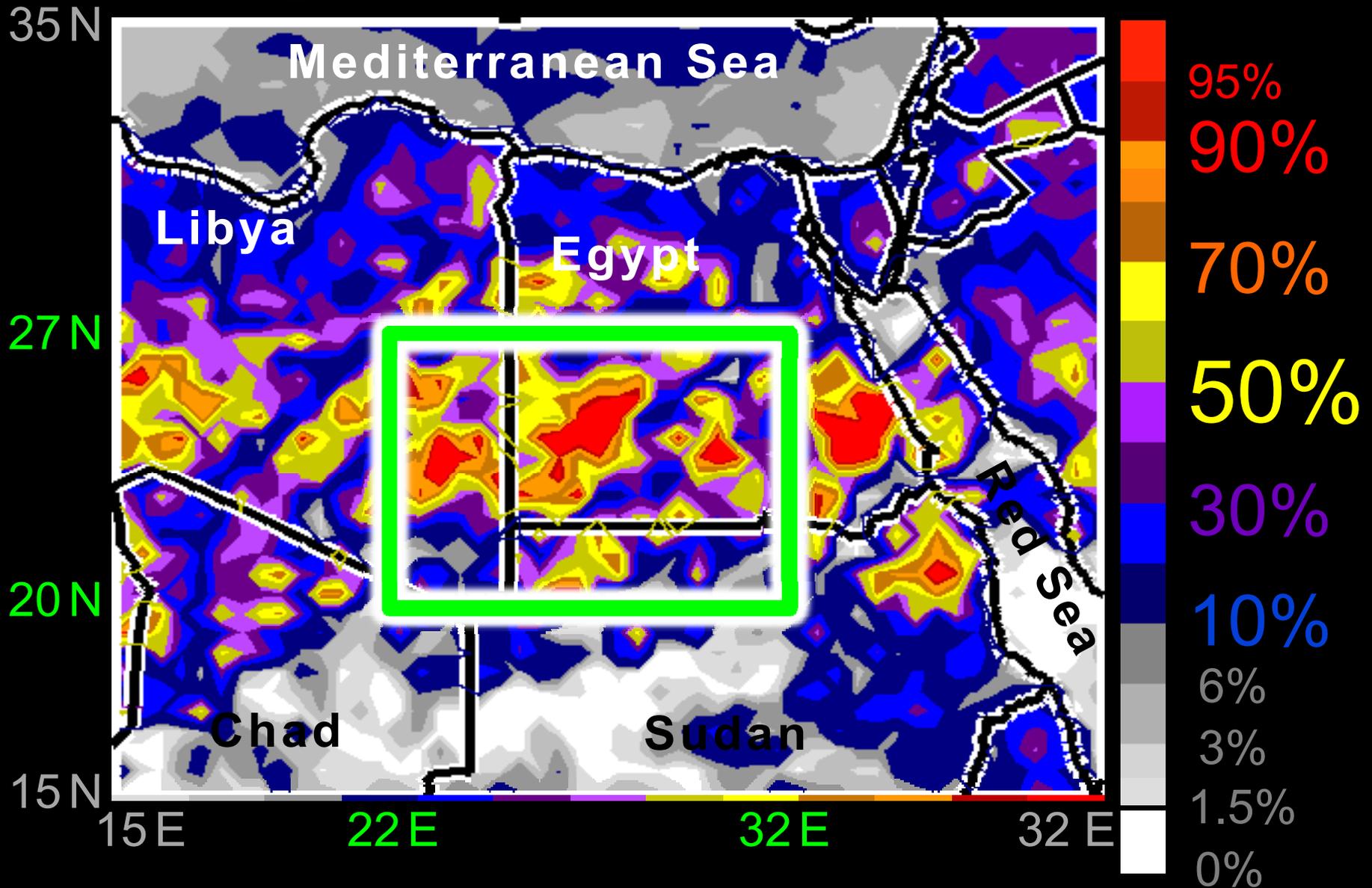


TRMM Precipitation Radar 1998-2012 (3A25) from Kelley (2014, *J. Climate*)

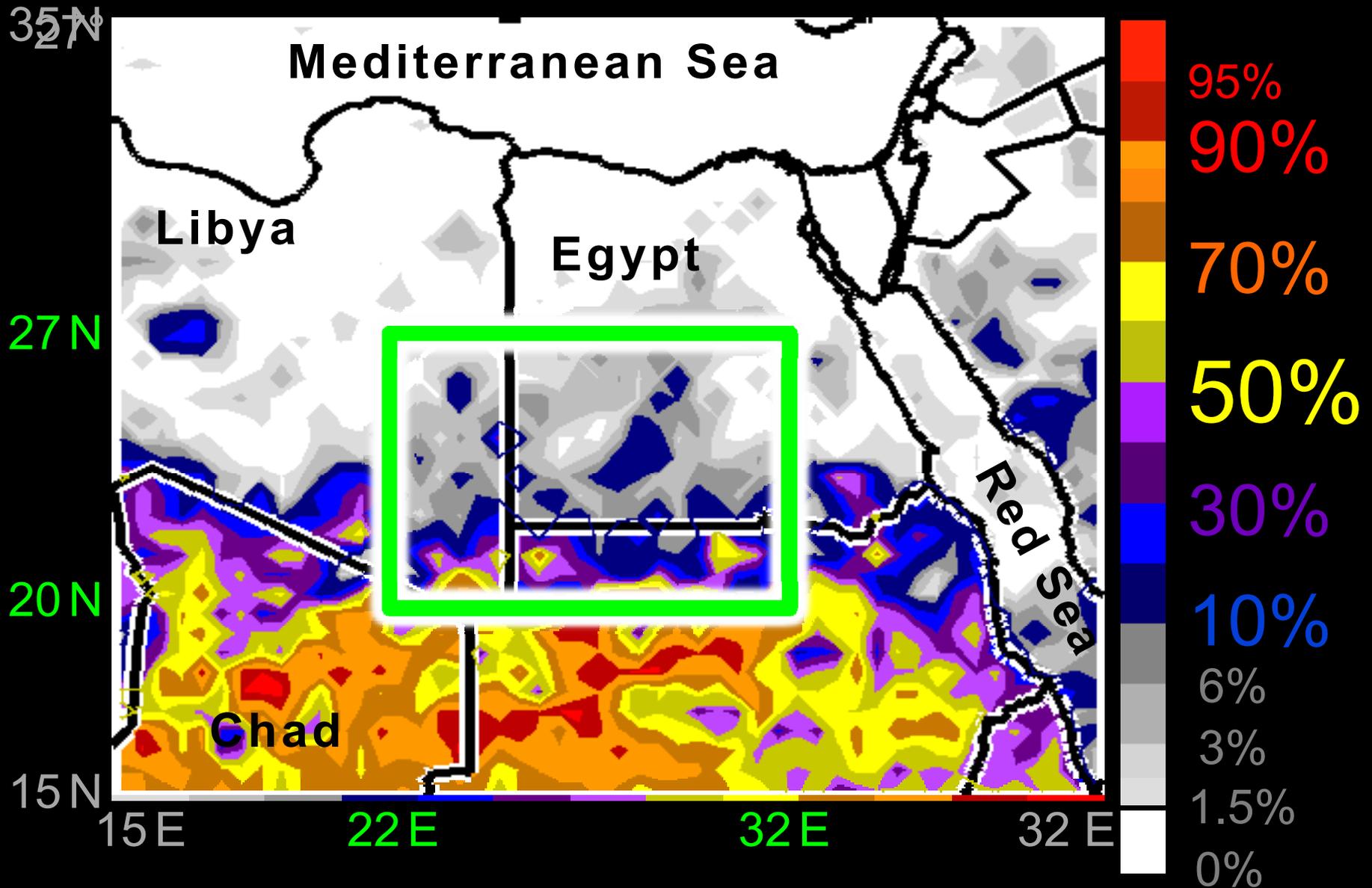
Winter Fraction of Annual Rain (Jan Feb)



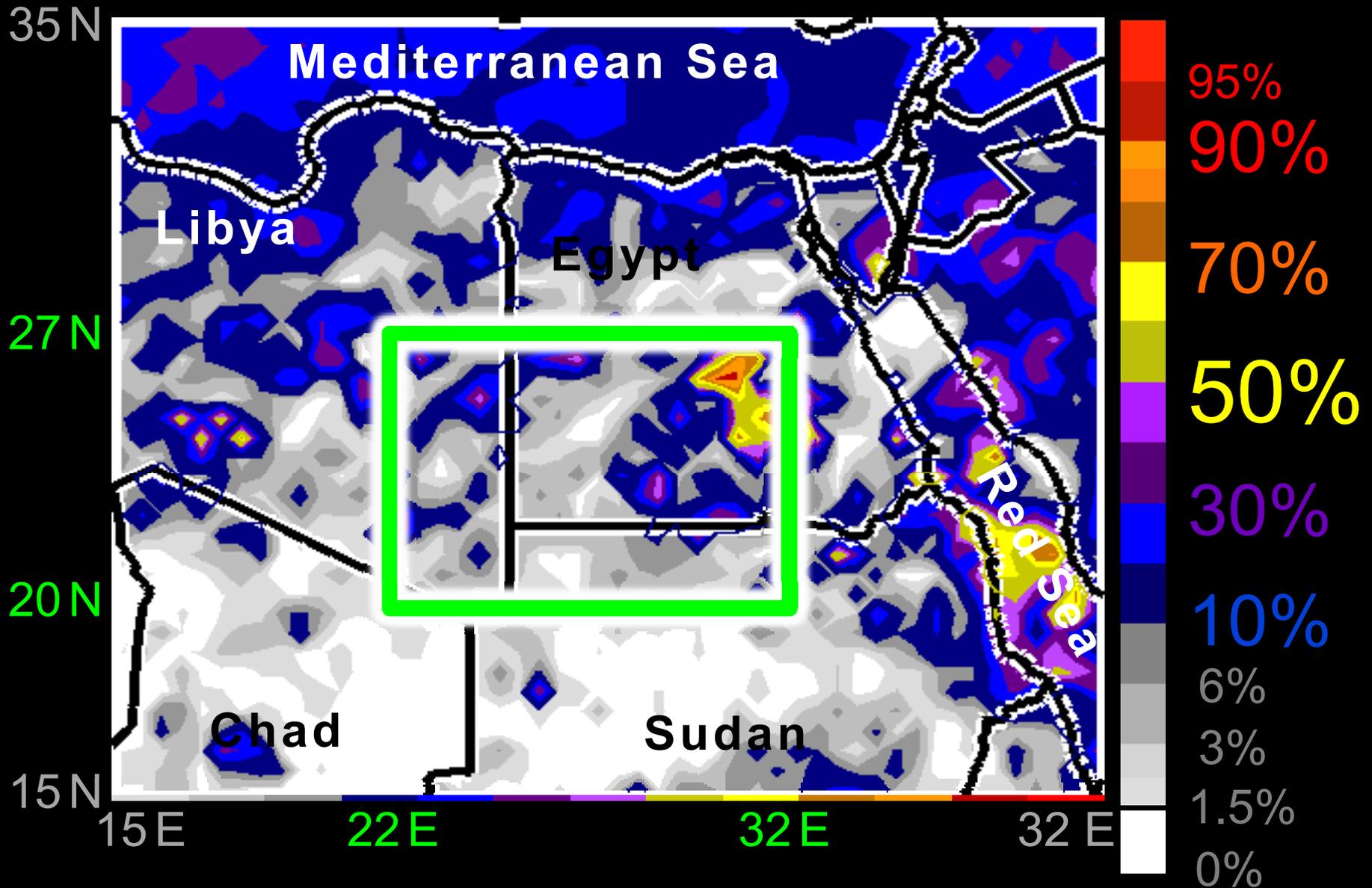
Spring Fraction of Annual Rain (Apr May)



Summer Fraction of Annual Rain (Jul Aug)



Autumn Fraction of Annual Rain (Oct Nov)



[4]

Double Checking

A Rain Gauge



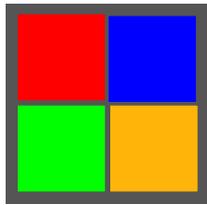
" The rainfall for a given day is the amount which has fallen during the 24 hours commencing at 0600 UT (8 AM LT) of that day. "

Egypt Meteor. Dept.,
Jan. 1970: *Monthly Weather Report*, pg. 6.
Available from the
NOAA Central Library.

Long-term Gauge Avg.

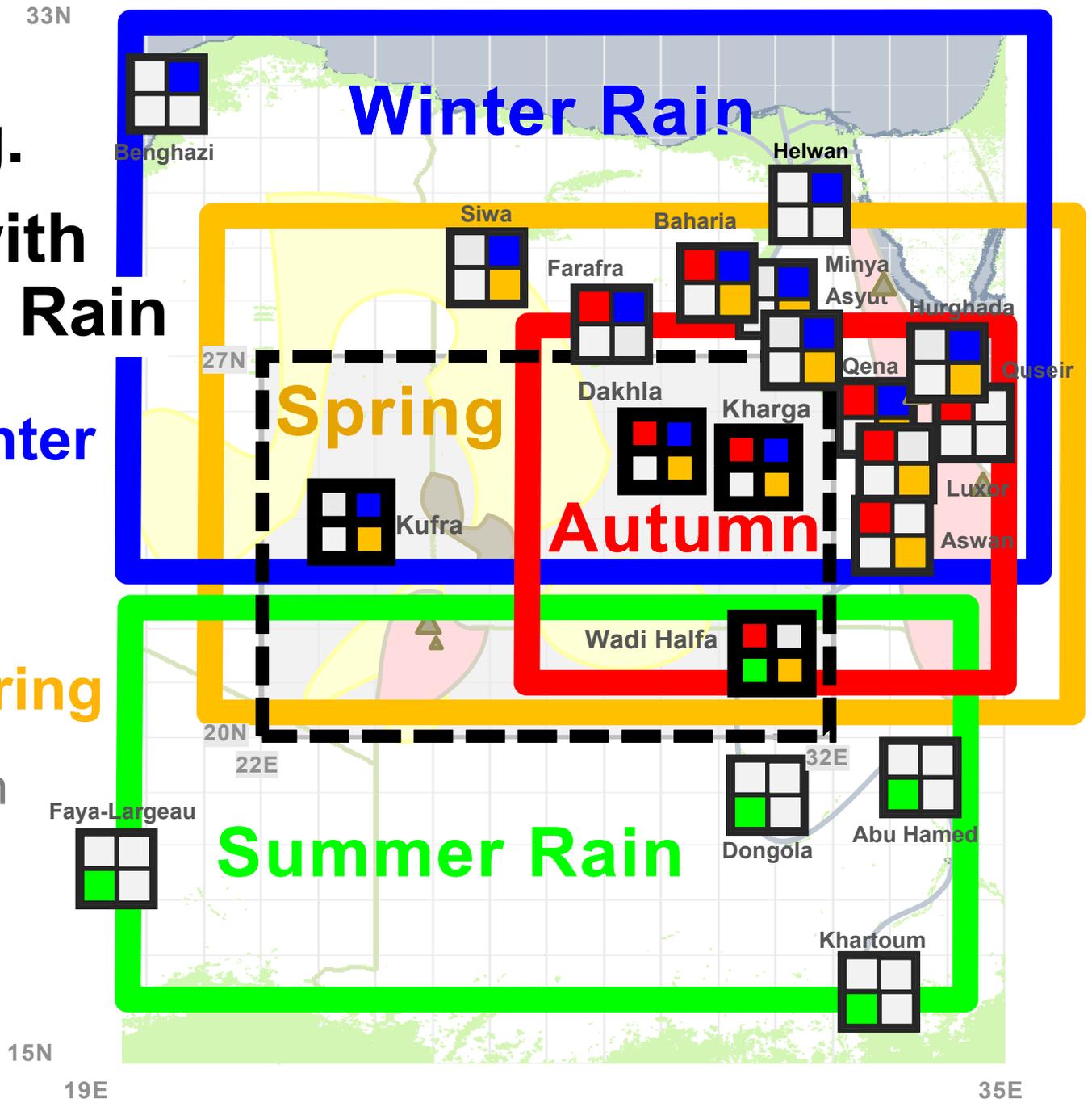
Seasons with Significant Rain

Autumn Winter



Summer Spring

-  Vegetation
-  Rocky
-  Plateau
-  Mountain
-  Sand

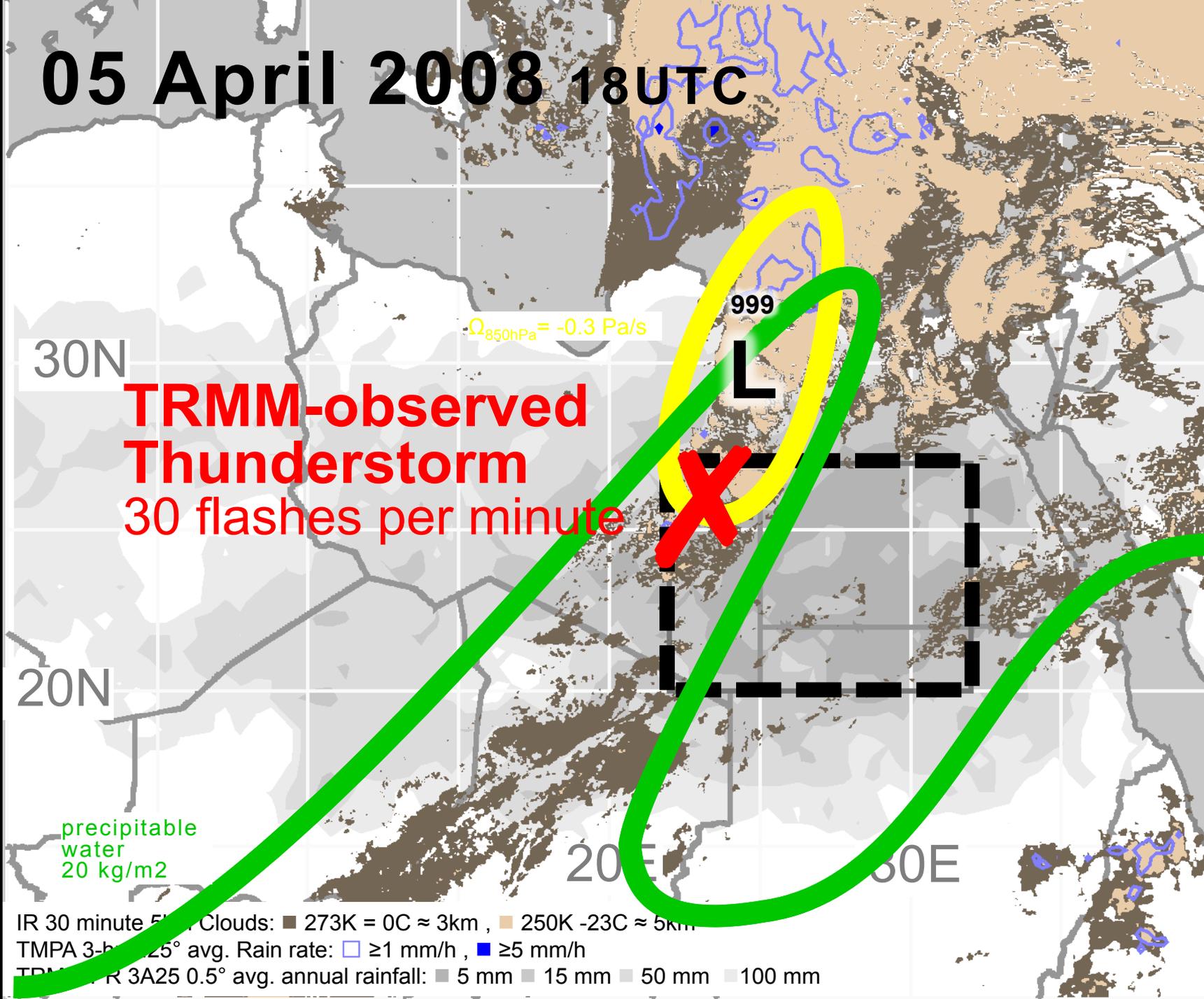


The Highest Flash Rate* in a Spring Storm 5 April 2008

TRMM LIS saw >50 flashes in a
precipitation feature 200 km across during
90 seconds of observation

* During 1998-2012

05 April 2008 18UTC



30N

**TRMM-observed
Thunderstorm**
30 flashes per minute

$-\Omega_{850hPa} = -0.3 \text{ Pa/s}$

999

L

20N

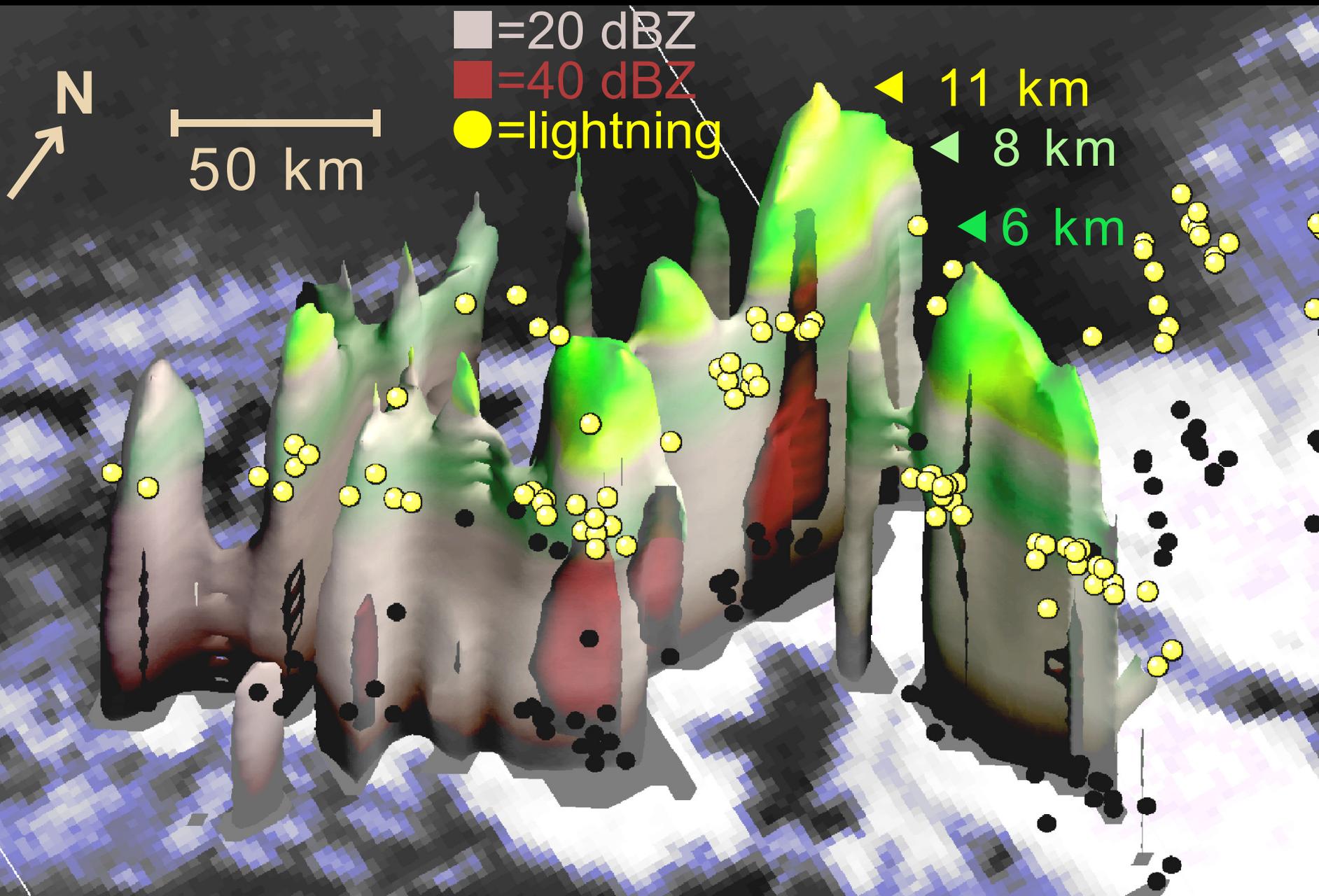
precipitable
water
20 kg/m²

20E

30E

IR 30 minute 5km Clouds: ■ 273K = 0C ≈ 3km , ■ 250K -23C ≈ 5km
TMPA 3-h 25° avg. Rain rate: □ ≥1 mm/h , ■ ≥5 mm/h
TRMM 3A25 0.5° avg. annual rainfall: ■ 5 mm ■ 15 mm ■ 50 mm ■ 100 mm

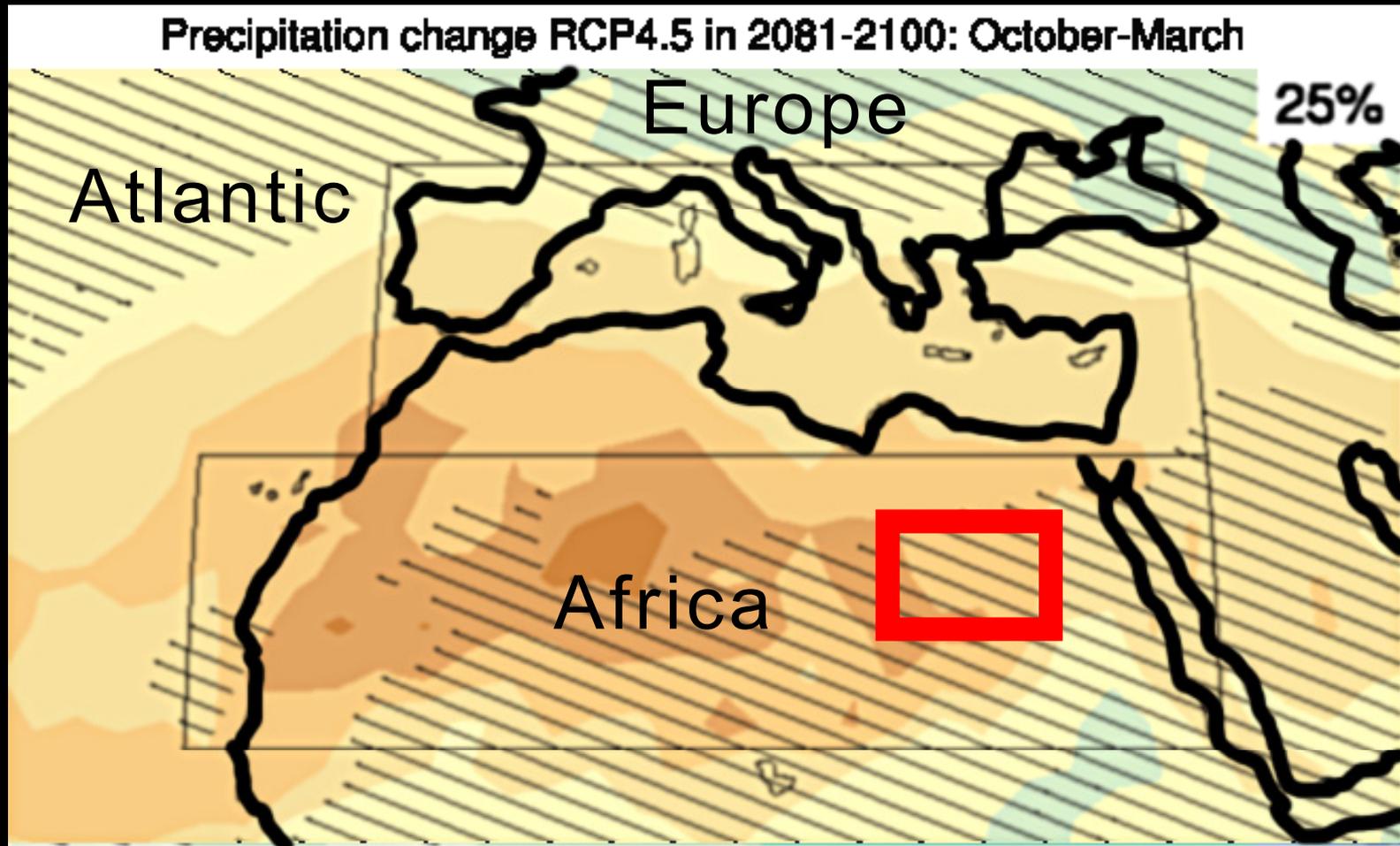
TRMM orbit #59193, 5 Apr 2008 1815UTC, 25.2N 22.4E



[5]

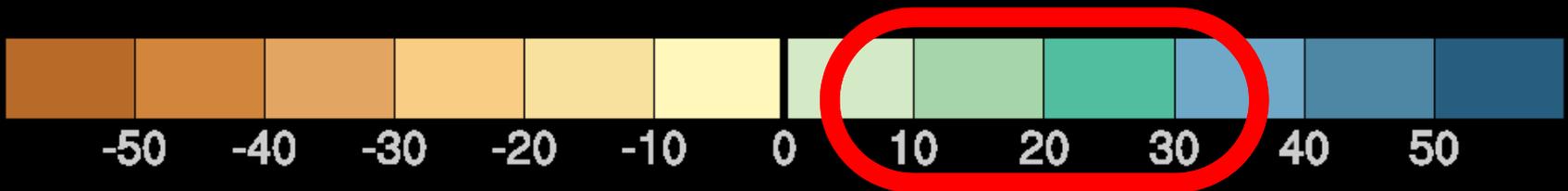
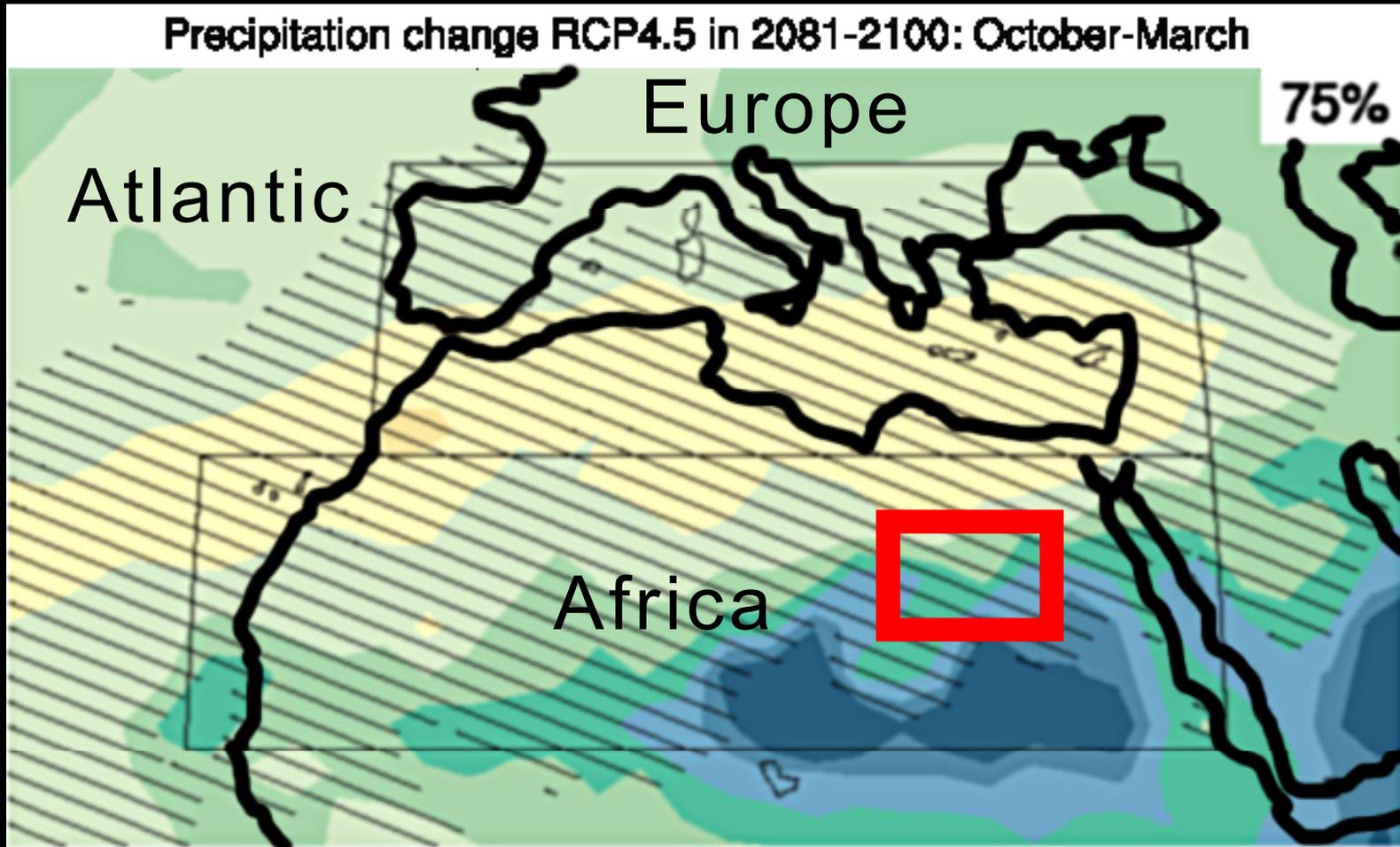
So what?

Some models say... 20-30% dryer in 2090



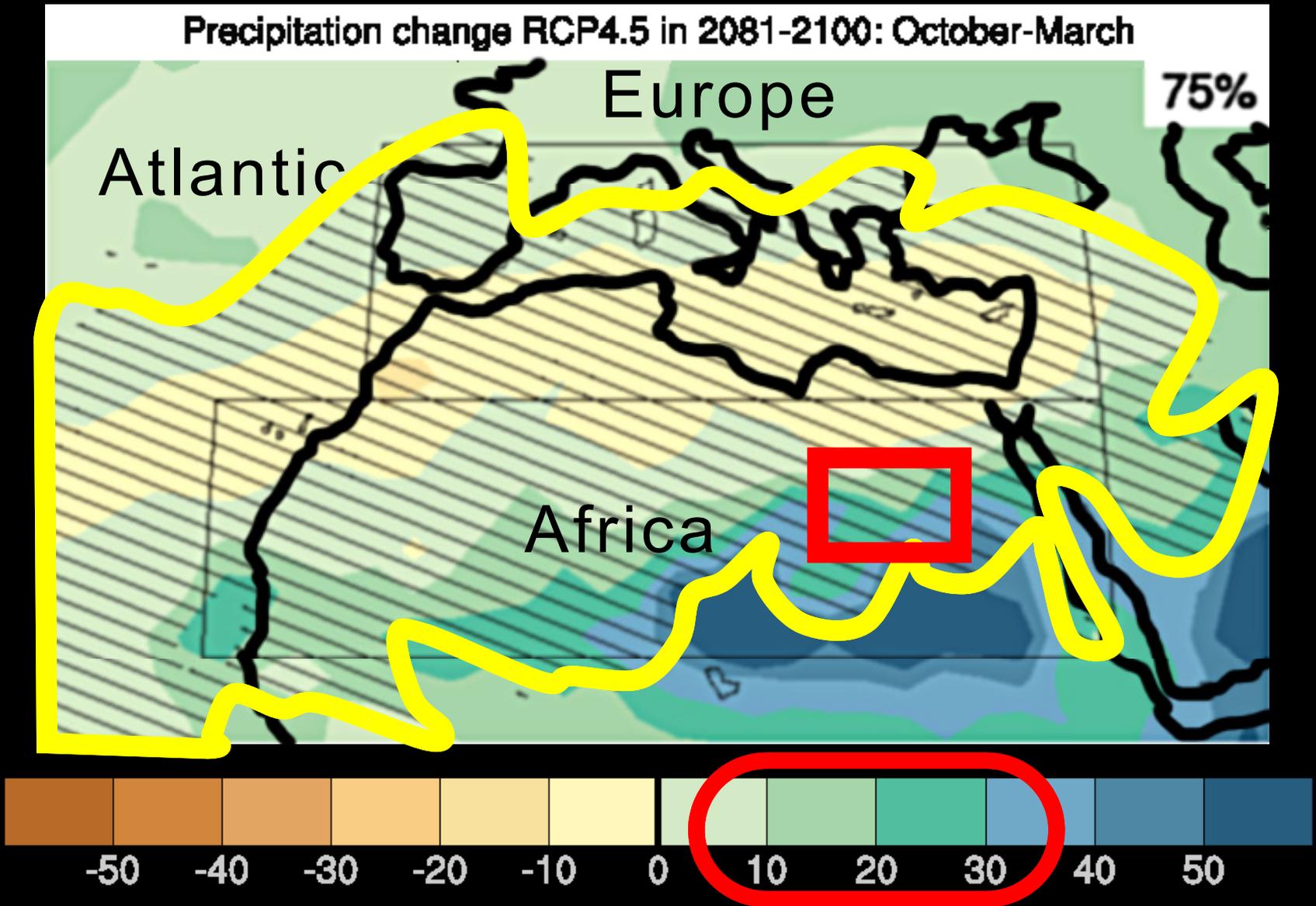
For a group of climate forecast models, the 25-75th percentile range of expected % change in annual precip accumulation over North Africa. Hashing: the 60 yr change (top) or 100 yr change (bottom) is less certain because the forecasted change is less than the natural variability during the past 20 years.

Other models say... 10-30% wetter in 2090



For a group of climate forecast models, the 25-75th percentile range of expected % change in annual precip accumulation over North Africa. Hashing: the 60 yr change (top) or 100 yr change (bottom) is less certain because the forecasted change is less than the natural variability during the past 20 years.

Other models say... 10-30% wetter in 2090



For a group of climate forecast models, the 25-75th percentile range of expected % change in annual precip accumulation over North Africa. Hashing: the 60 yr change (top) or 100 yr change (bottom) is less certain because the forecasted change is less than the natural variability during the past 20 years.

A penny is 1.5 millimeters thick



Shallow rain depth, BUT significant energy is transferred to the atmosphere

This thin layer of rain is an average for every square meter of a very large area, an area almost as large as the southeast United States.

A 2 mm depth of rain over 20-27°N Latitude, 22-32°E Longitude would fill a cube with sides 4.6 kilometer long.

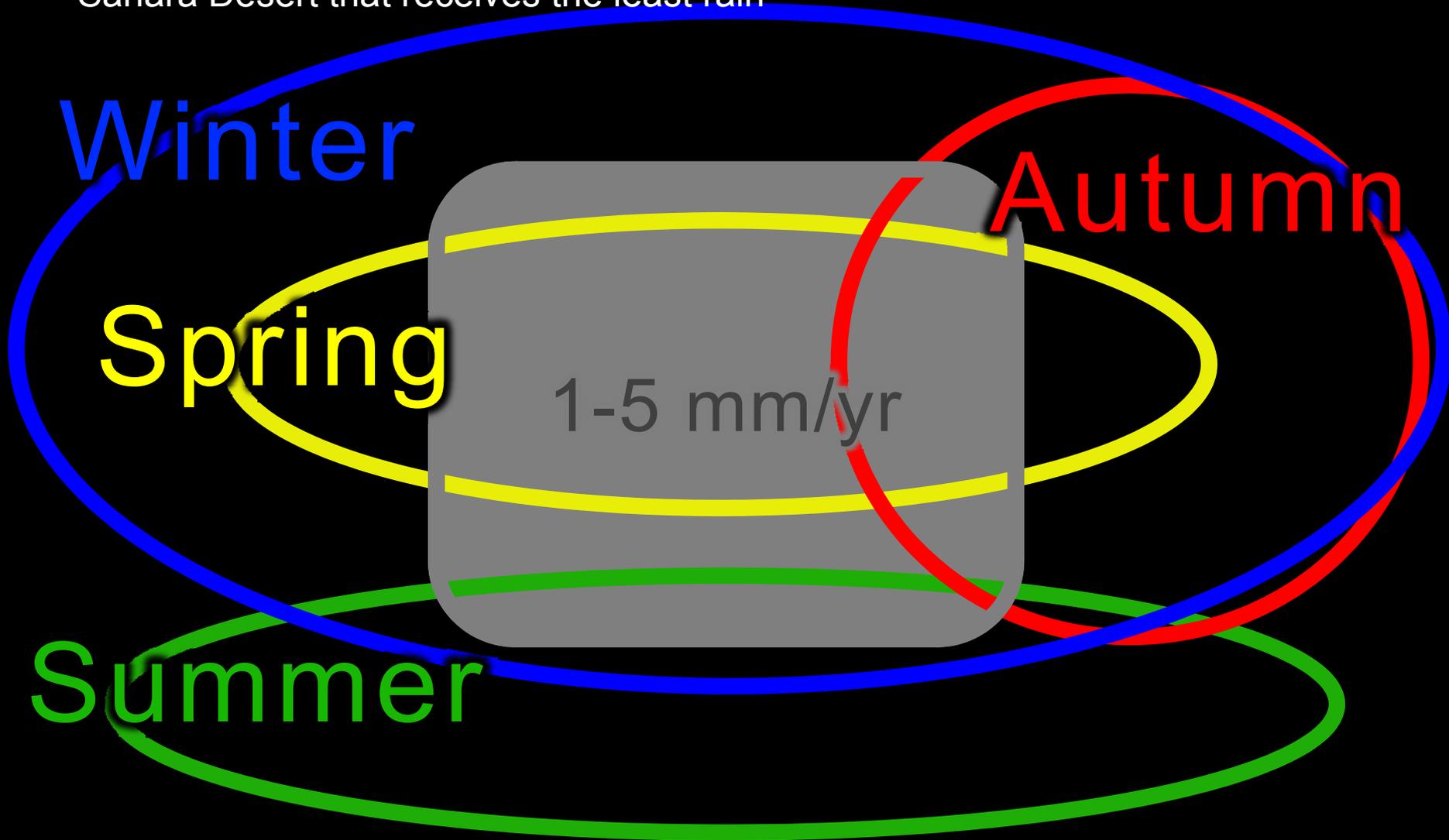
The latent heat release with vapor condensing to form 2 mm of rainfall is 1 watt per square meter during the 2 month rainy season.

[6]

Summary

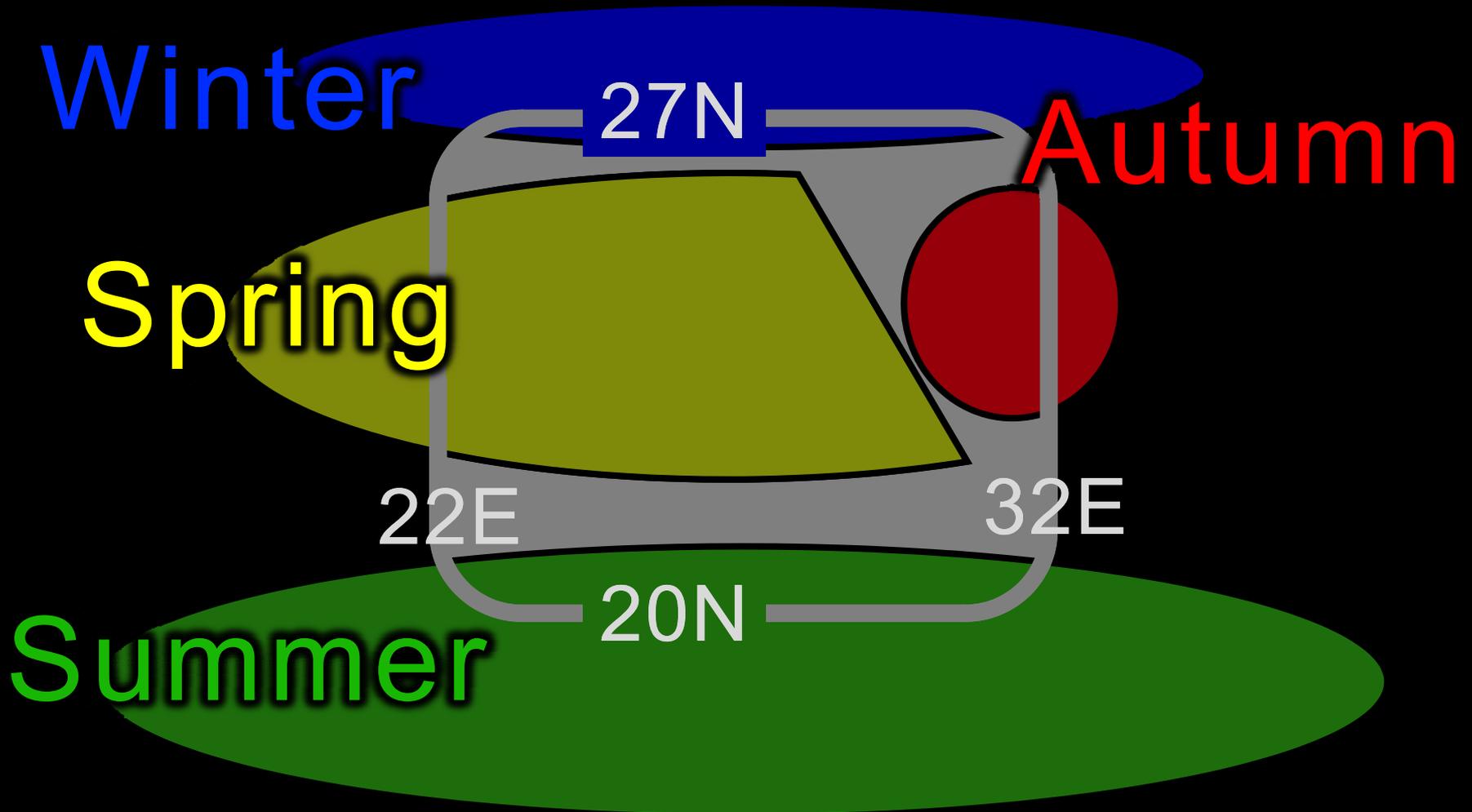
Rain Detection

The TRMM satellite radar observes rain in all four seasons over the part of the Sahara Desert that receives the least rain



Dominant Rainy Season

On average, most of the year's rain falls in one of these four seasons over specific locations within the part of the Sahara Desert that receives the least rain



References

- Egypt Meteor. Dept., 1900-1970: *Meteorological Report for the Year*. NOAA Central Library Data Imaging Project:
http://docs.lib.noaa.gov/rescue/data_rescue_egypt.html.
- Kelley, O. A., 2014: Where the least rainfall occurs in the Sahara Desert, the TRMM radar reveals a different pattern of rainfall each season. *J. Climate*, in press, doi: 10.1175/JCLI-D-14-00145.1.
- Liebmann, B., I. Bladé, G. N. Kiladis, L. M. V. Carvalho, G. B. Senay, D. Allured, S. Leroux, and C. Funk, 2012: Seasonality of African precipitation from 1996 to 2009. *J. Climate*, 25, 4304–4322.
- Nicholson, S. E., 2011: *Dryland Climatology*. Cambridge U. Press, 516 pp.

Acknowledgements: This work was supported by the NASA METS-II contract. PPS provided computational facilitates. The staff of the NASA Goddard Library located hard-to-find documents and datasets.