Portraying the Geophysiology of the Okavango Delta, Botswana

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UNIGIS 2000 Seminar, Geoinformation Practice and Profession

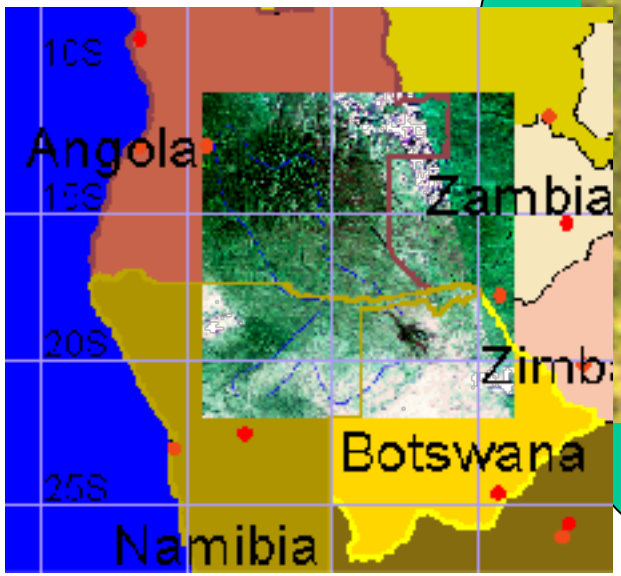
Three ”nested” hierarchical scales for portraying the natural geography of the Okavango Delta

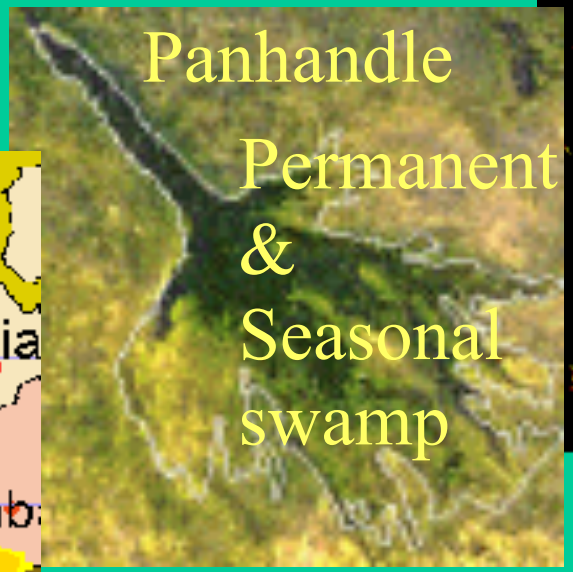
Focus of this study

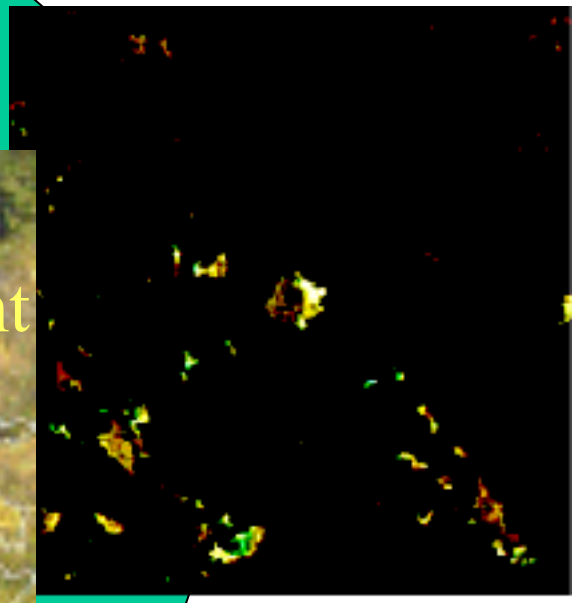
Component scale

Main Scale

Constraining scale







The Catchment

The Delta

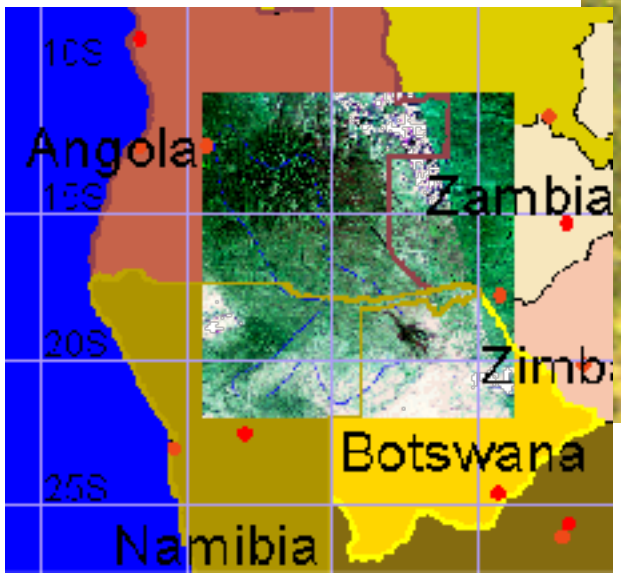
Islands, channels and lakes

Scale related problems of the Okavango Delta

Climate variation and change. Plans for abstraction and damming of water

Poor knowledge of hydrology and floods

Poor quantitative estimates



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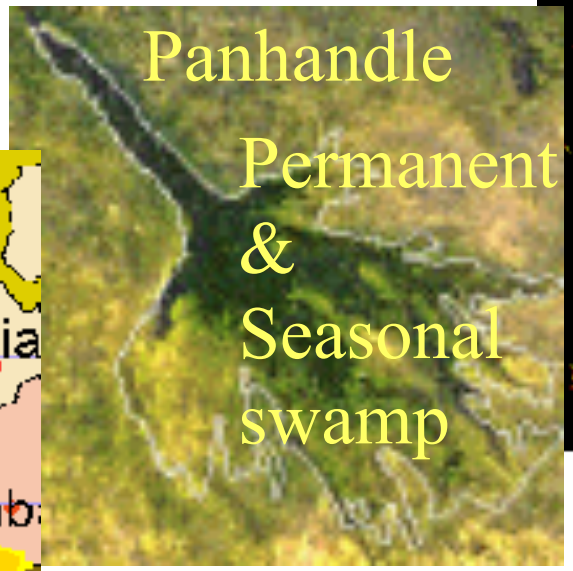

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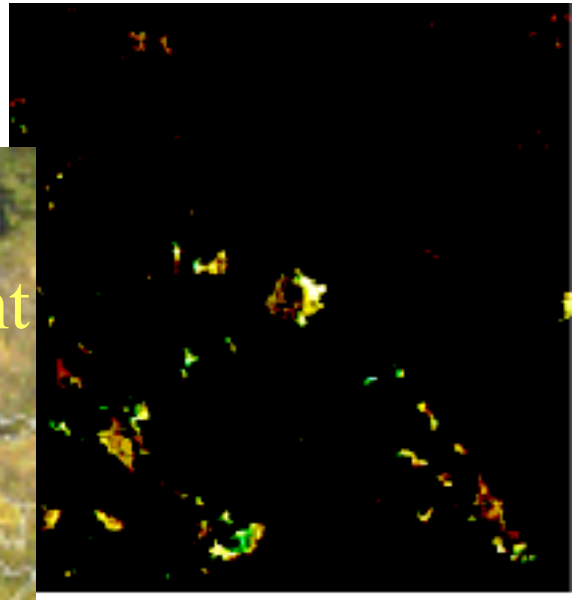


Islands, channels and lakes

Objectives

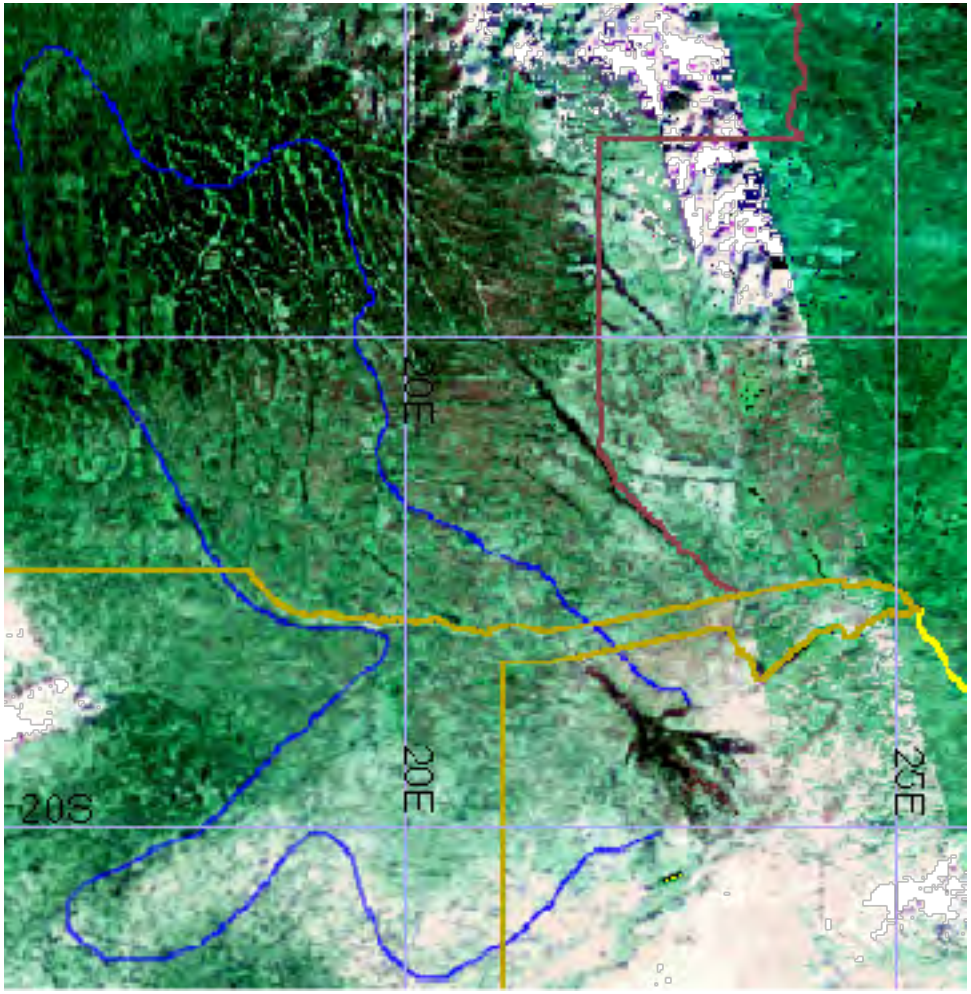
Quantitative estimates and timing of the annual flood
Quantitative estimates of the annaul vegetation cycle
Create a digital elevation model
Create a database for hydrological modeling efforts
Develop a method for object oriented classification of major delta components

Data capture

Data capture at three scales, representing the chosen hierarchical scales of study

Constraining scale Data capture – 1:1 miljon, 1-10 km grain size

- Digital Chart of the World, DCW
- GTOPO30
- NOAA-AVHRR
  (NDVI, cloud cover, cloud temperature)
- METEOSAT

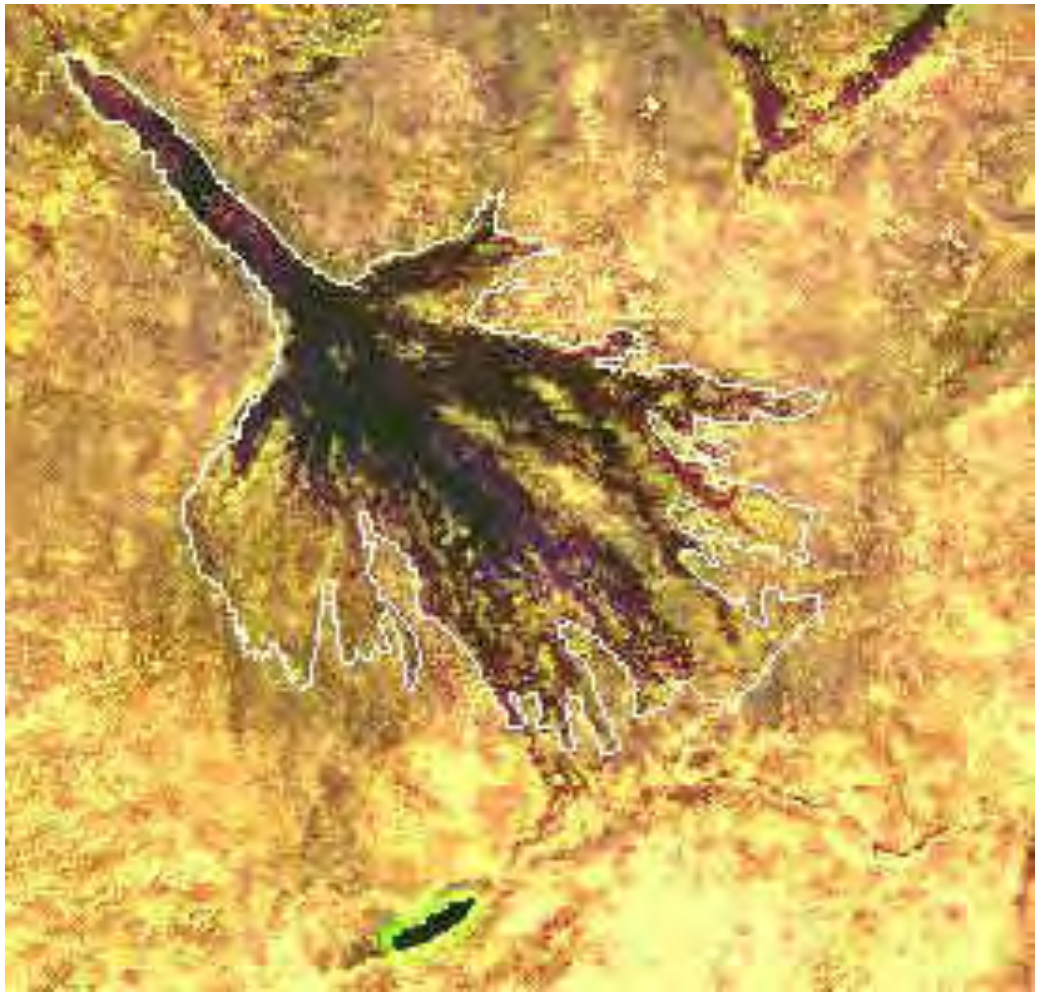


False colour composite from NOAA-AVHRR, October 1992, boarders from DCW

Main scale Data capture – 1:300 000, 1 km grain size

- Digital Chart of the World, DCW (Infrastructure)
- NOAA-AVHRR
- ERS2-ATSR

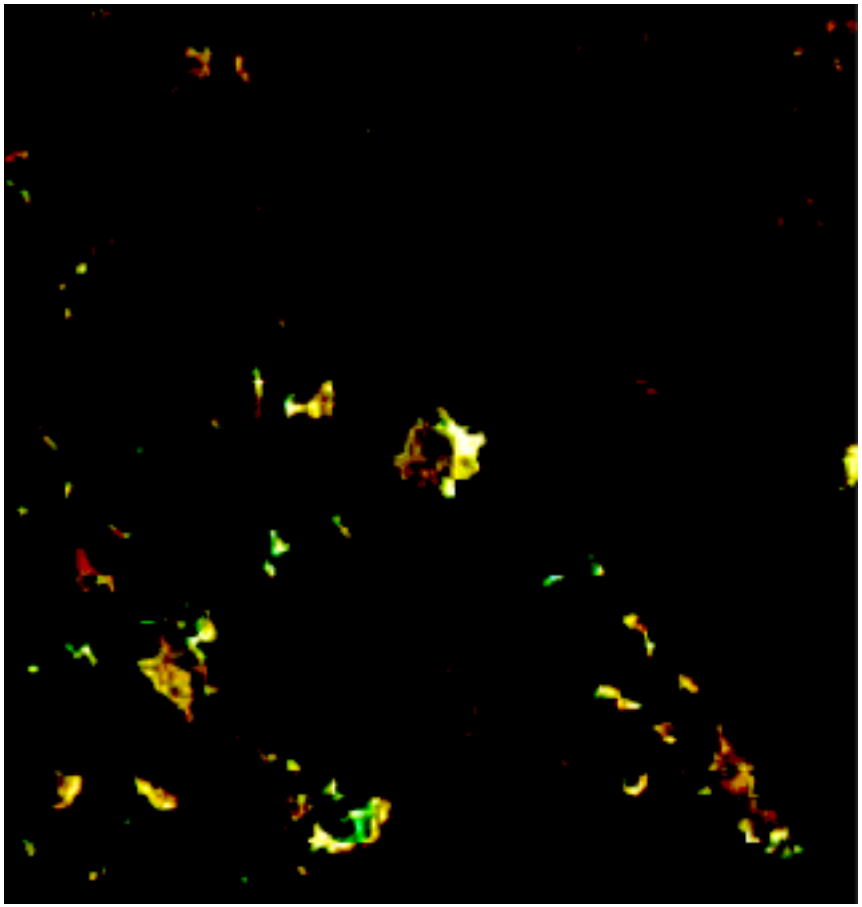
  (NDVI, water, cloud, LUCC)
- Elevation Surveys



False colour composite from NOAA-AVHRR, October 1992, digitised maximum extent of Delta

Component scale
Data capture – 1:50 000, 10-250 m grain size

- Digitising from 1:50 000 scale maps
- Field surveys
- Landsat TM
- SPOT
- TERRA
- SAFARI 2000



False colour composite
from Landsat TM,
July 1994

INTERMEDIATE SCALE

Archived NOAA-AVHRR 10-day composites from www parts of the years 1992, 1993, 1995 and 1996

Georeferencing and other problems

NOAA-AVHRR 10 day composite of the

Okavango Delta

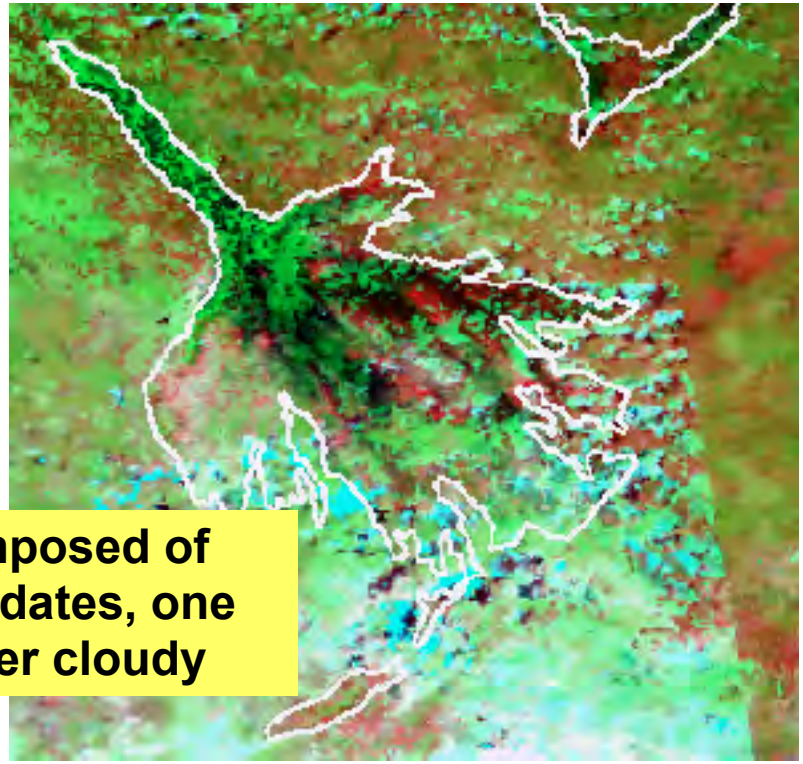
Image composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Composed of two dates, one rather cloudy

Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

N

100 Km

1992

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

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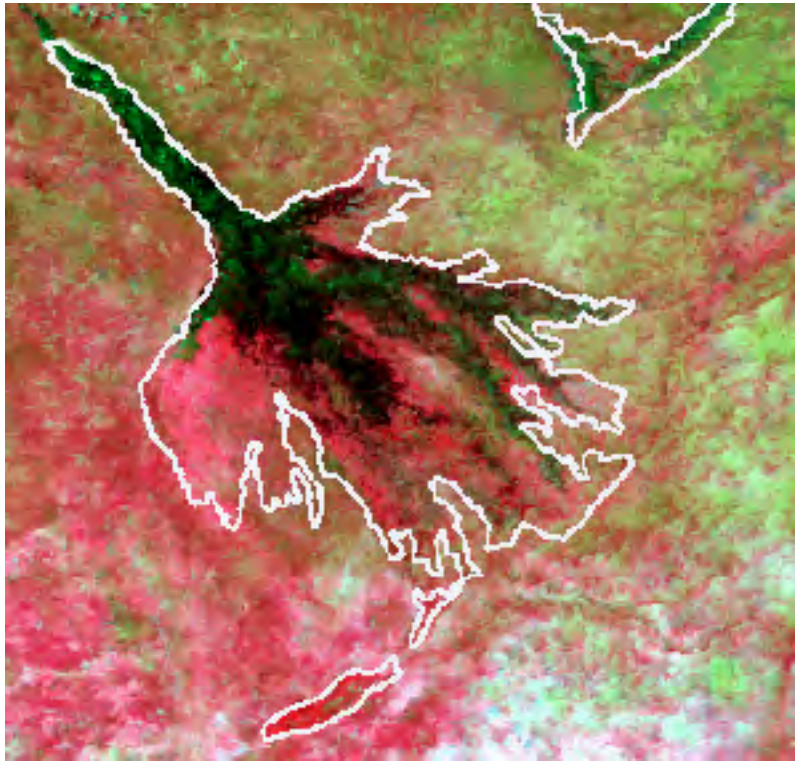

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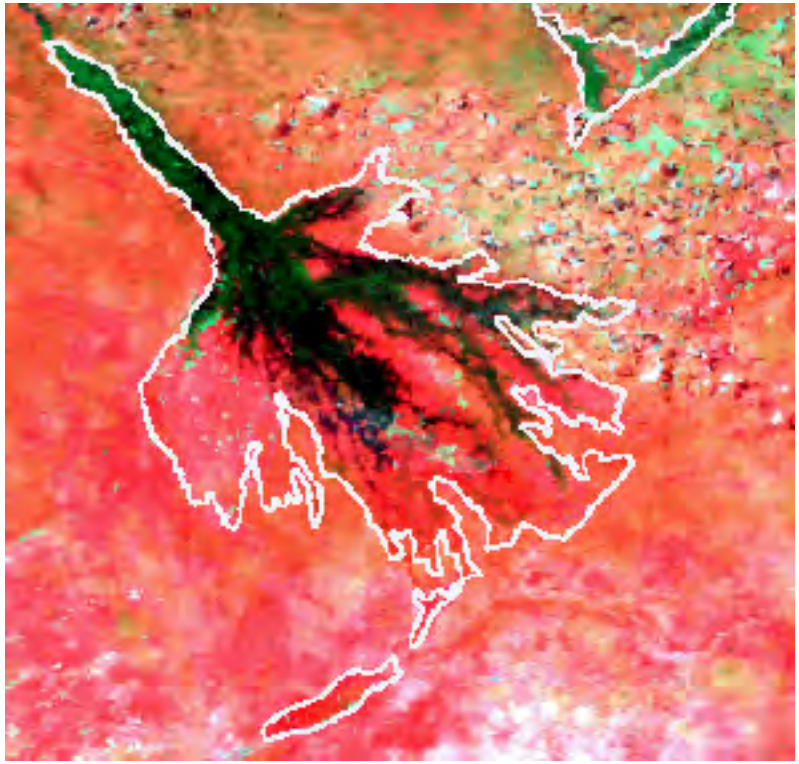

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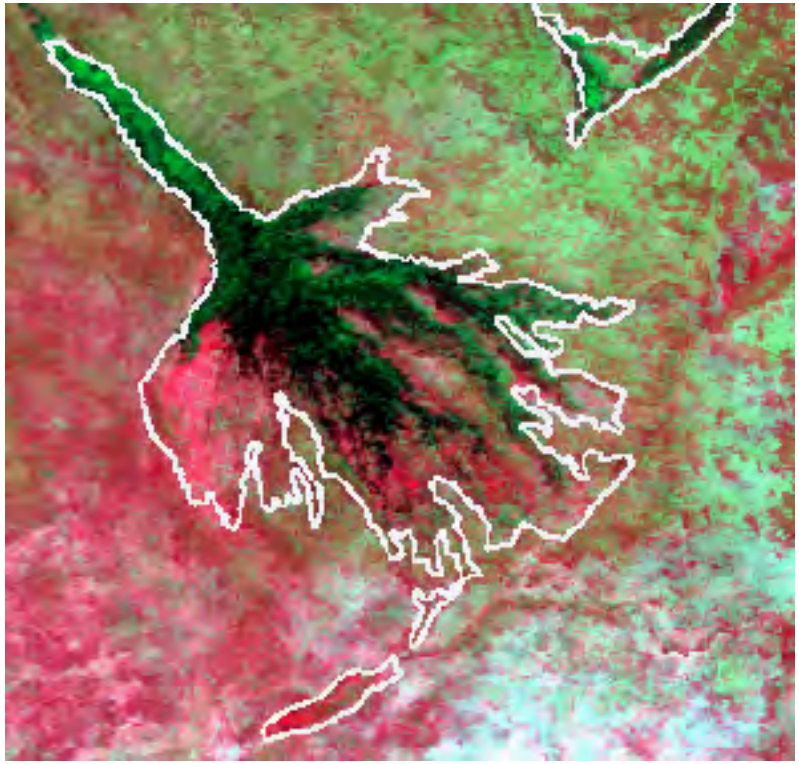

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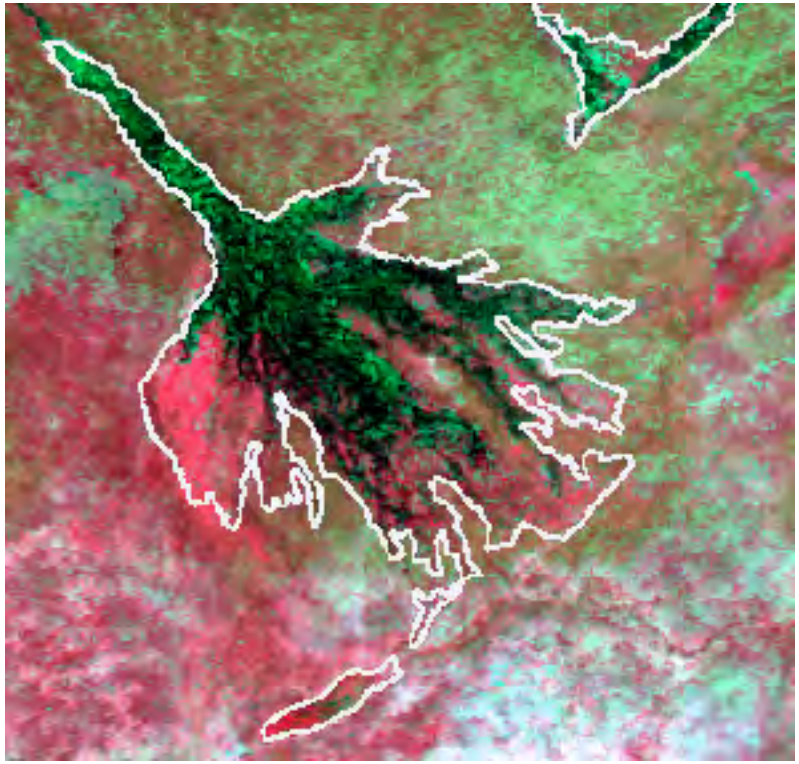

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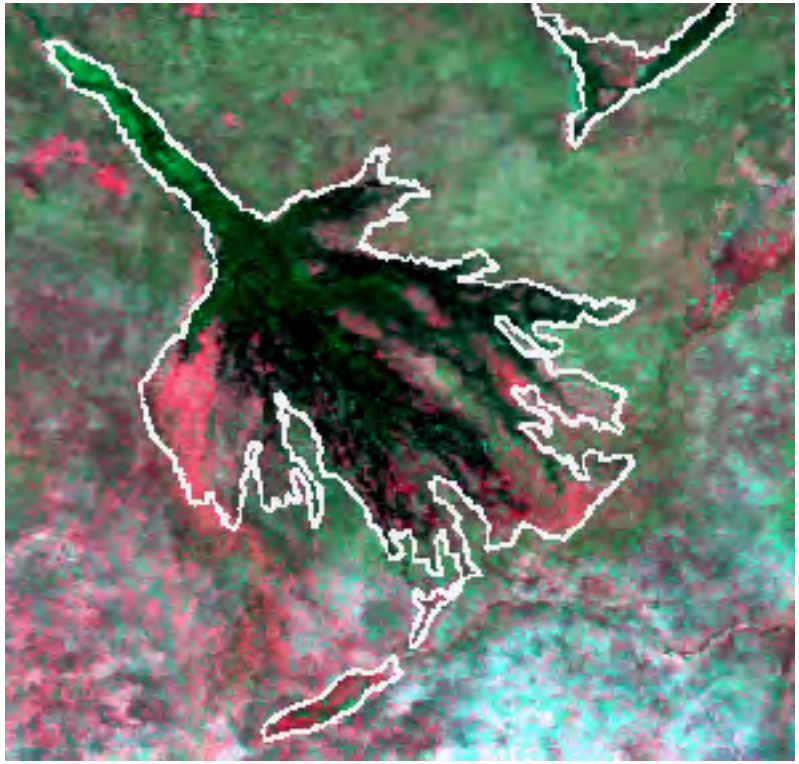

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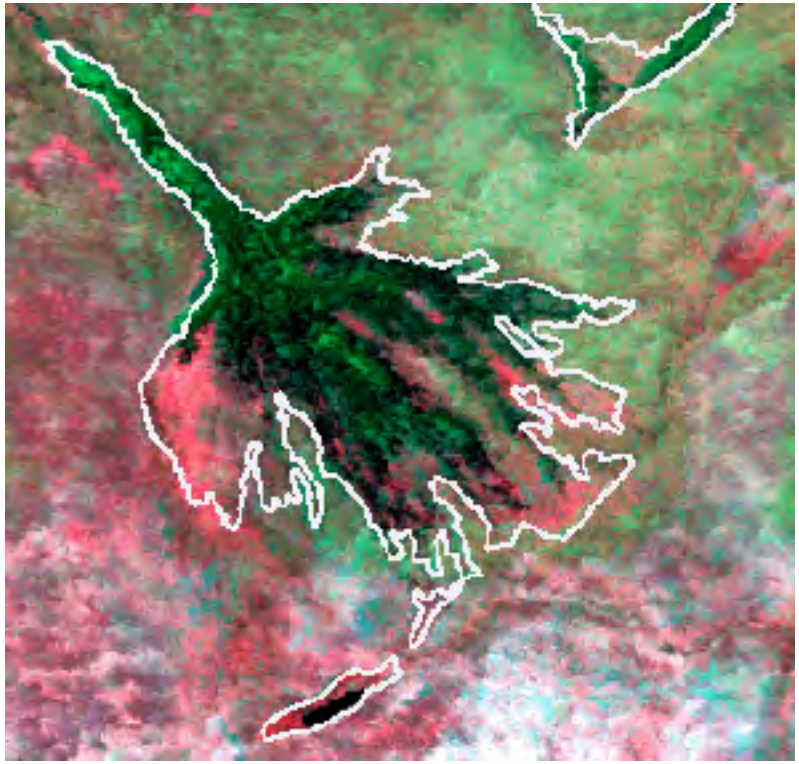

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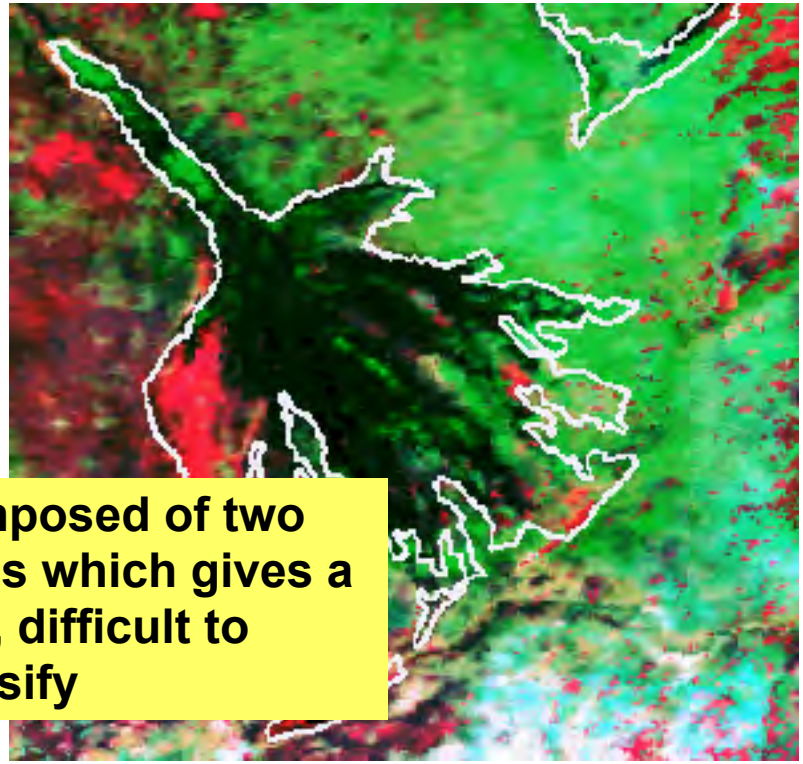

Composed of two dates which gives a blur, difficult to classify

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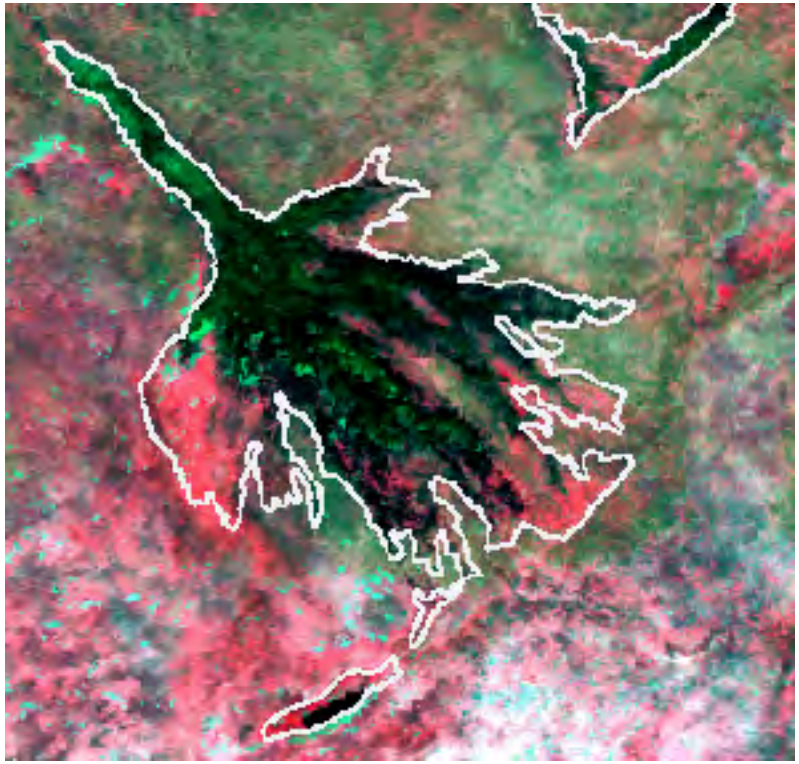

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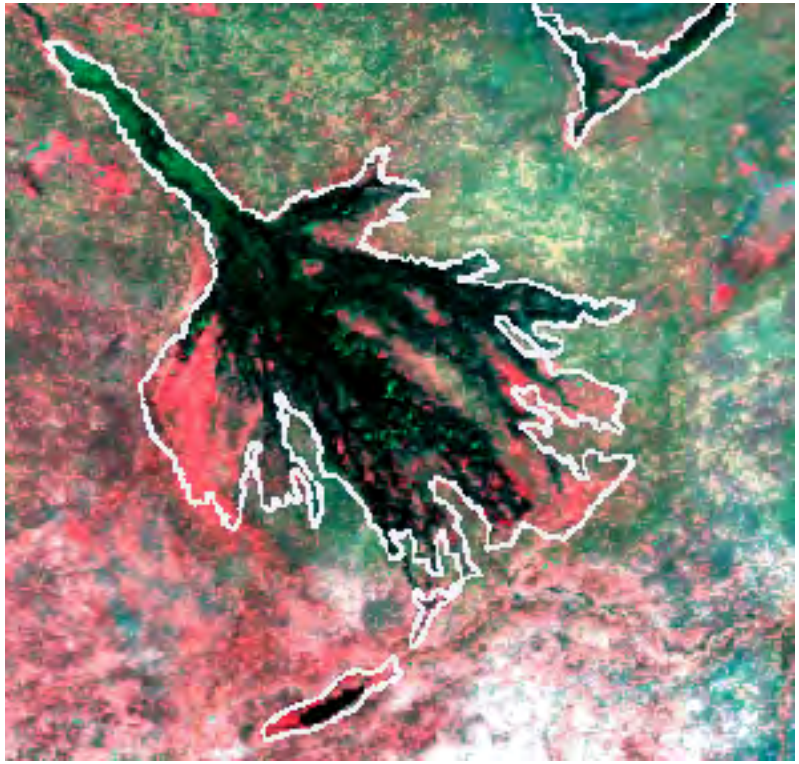

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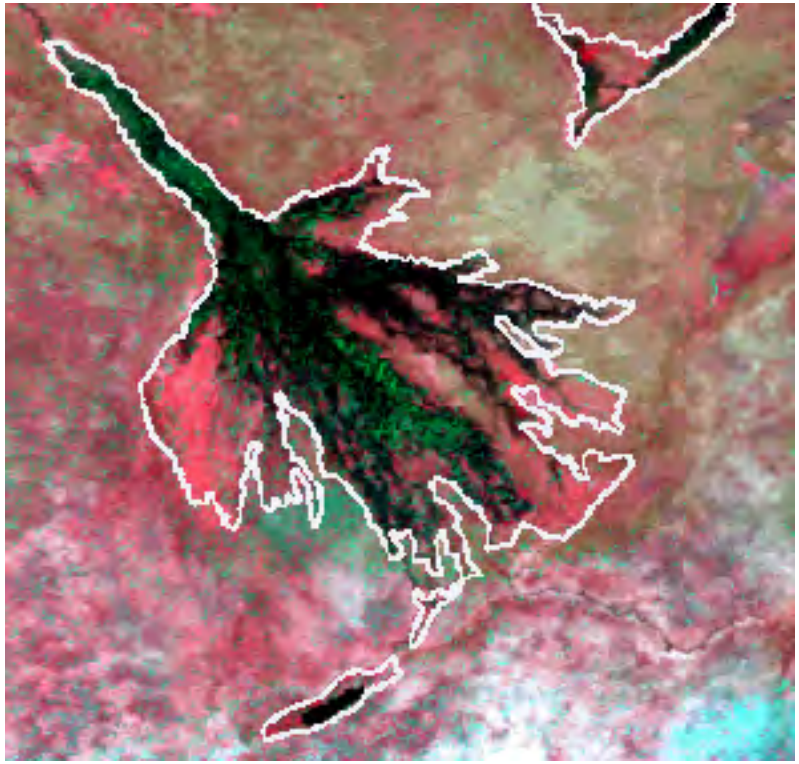

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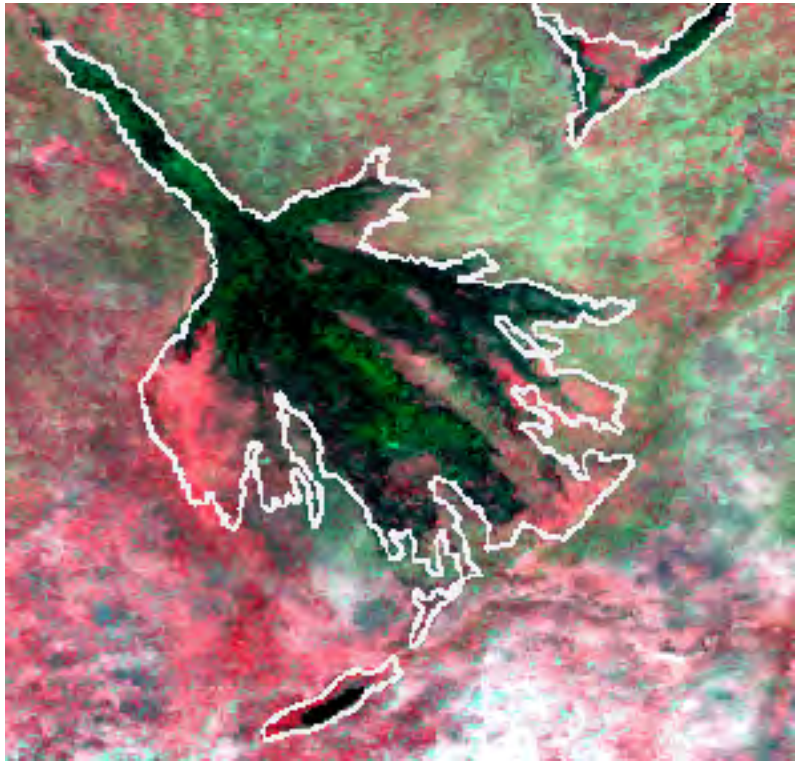

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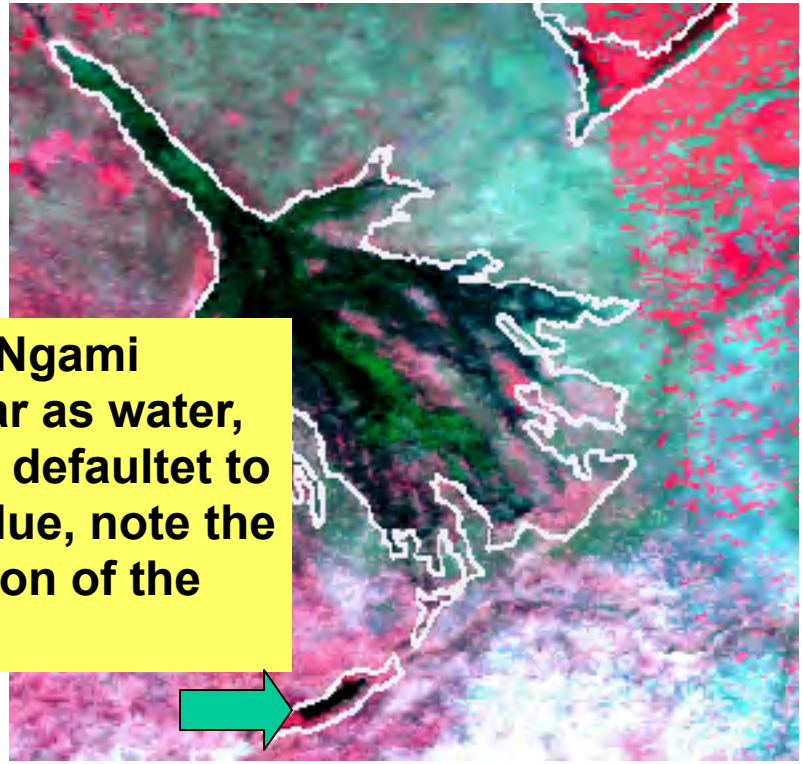

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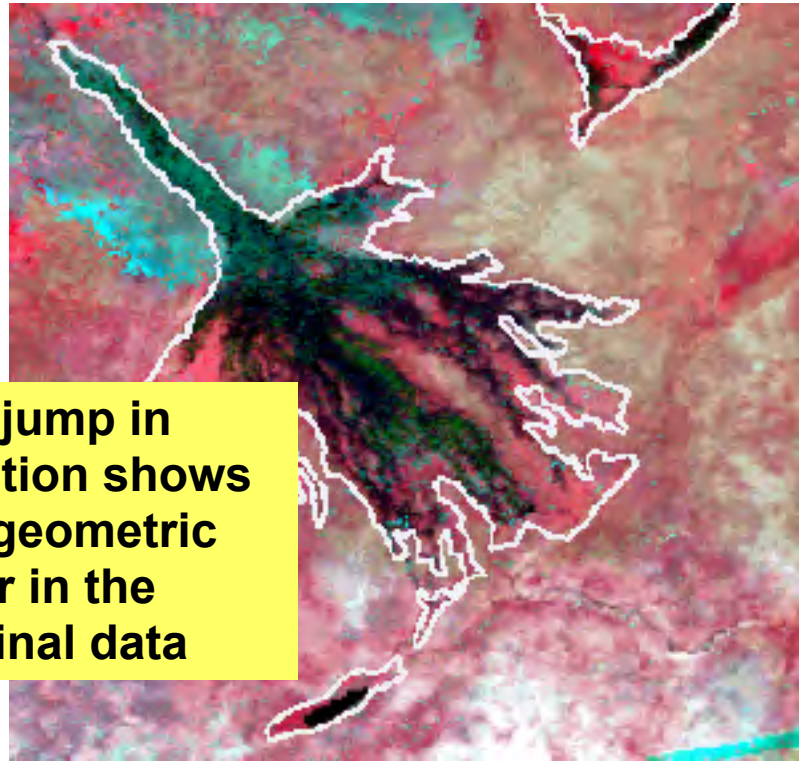

The jump in position shows the geometric error in the original data

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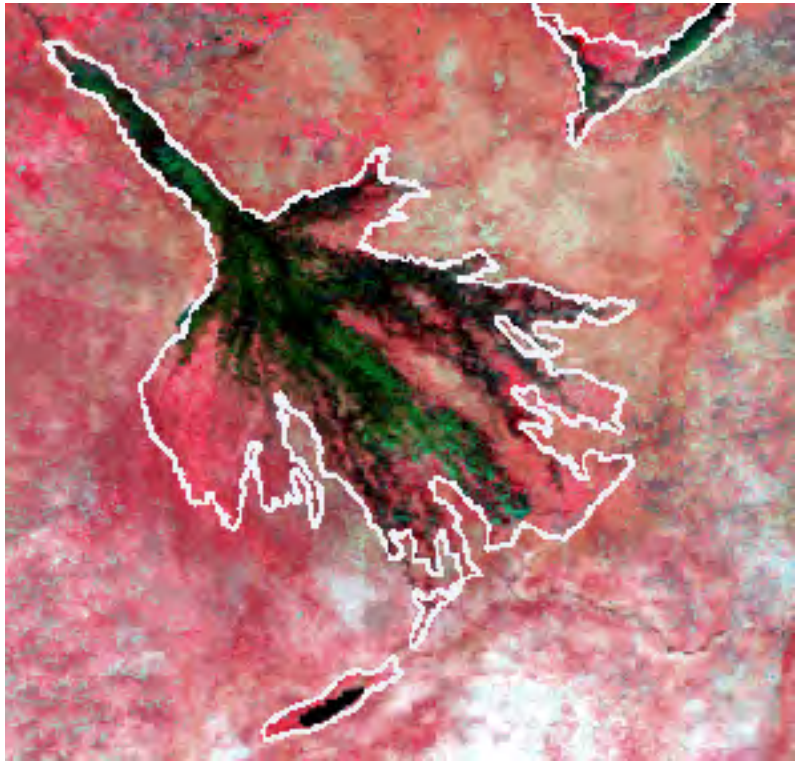

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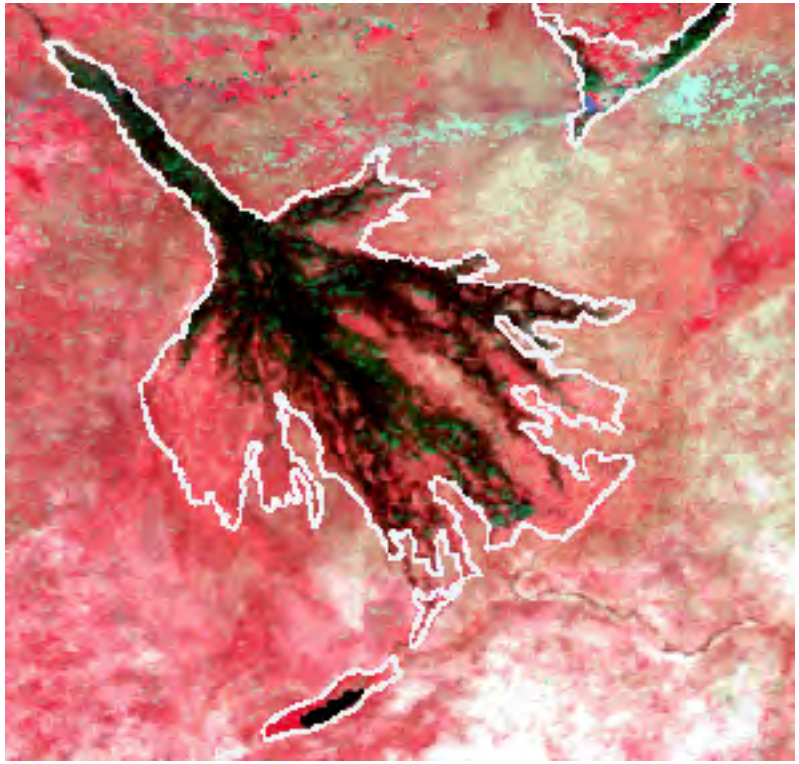

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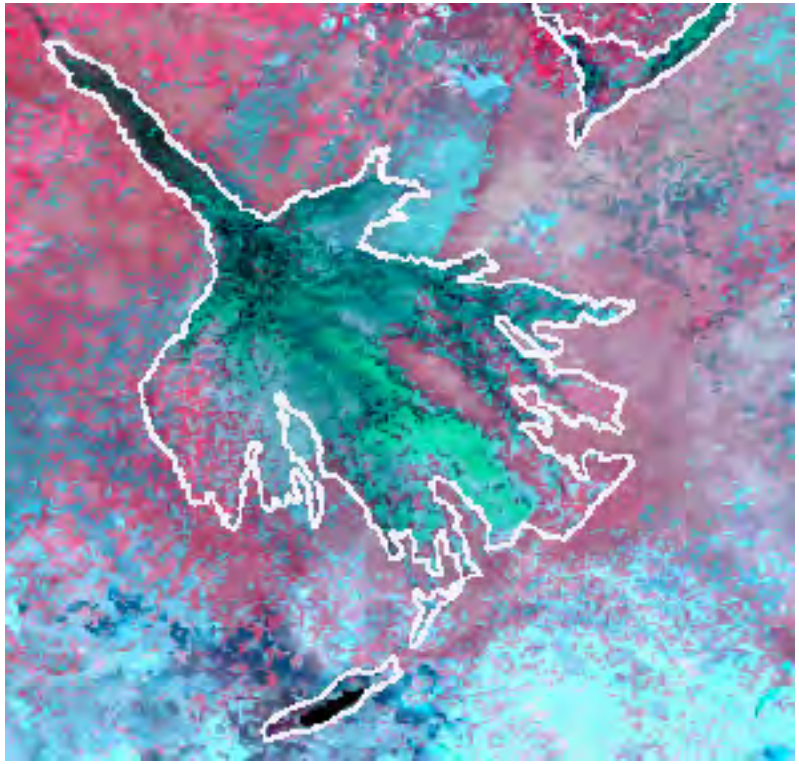

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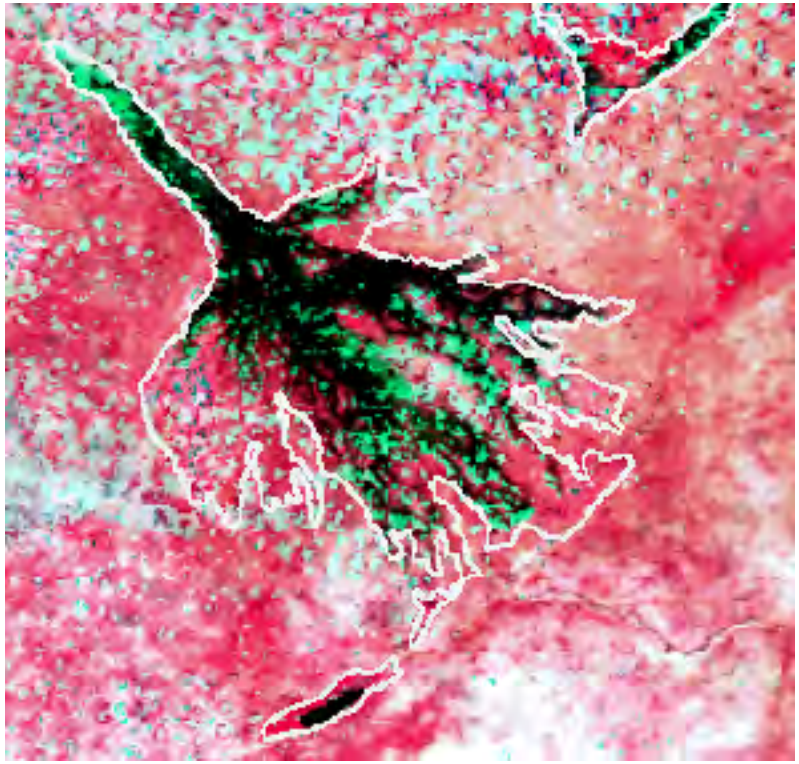

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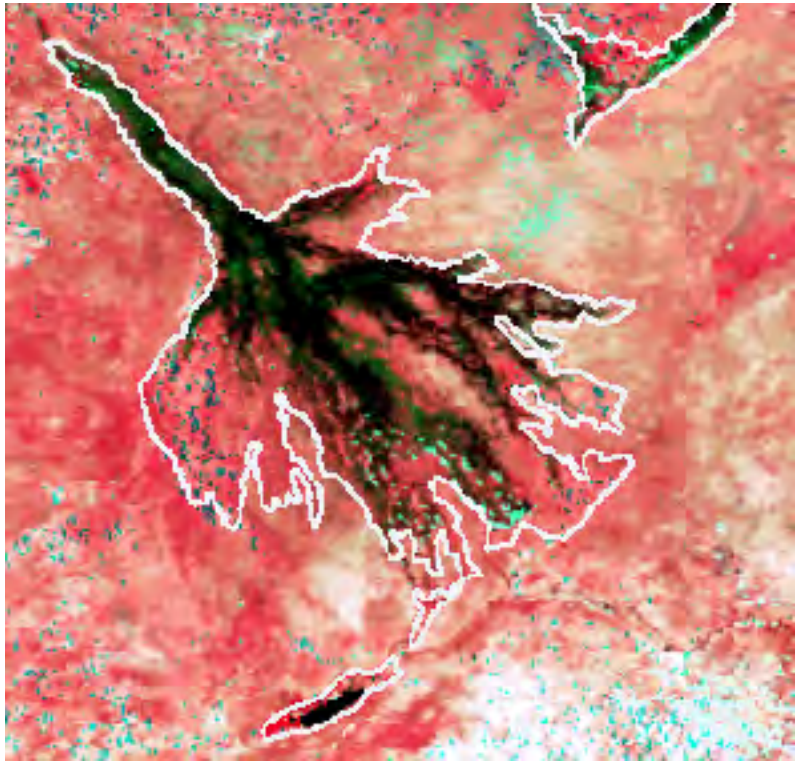

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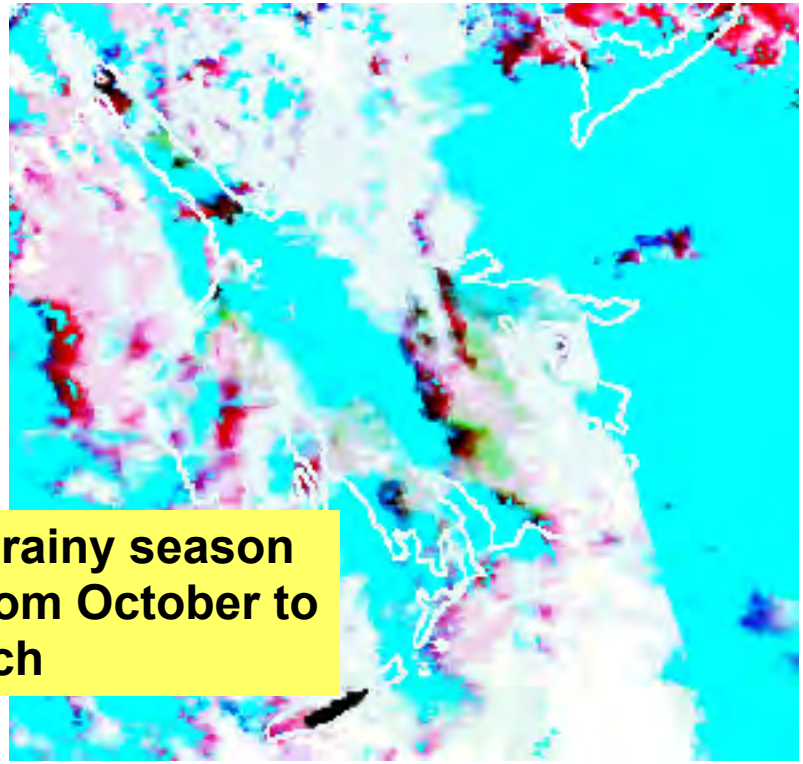

The rainy season is from October to March

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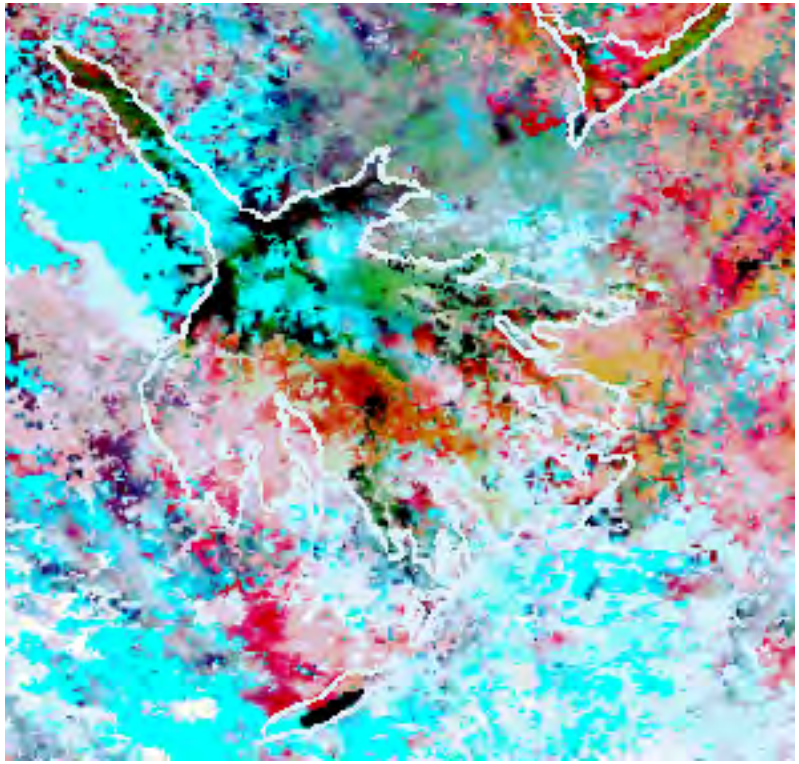

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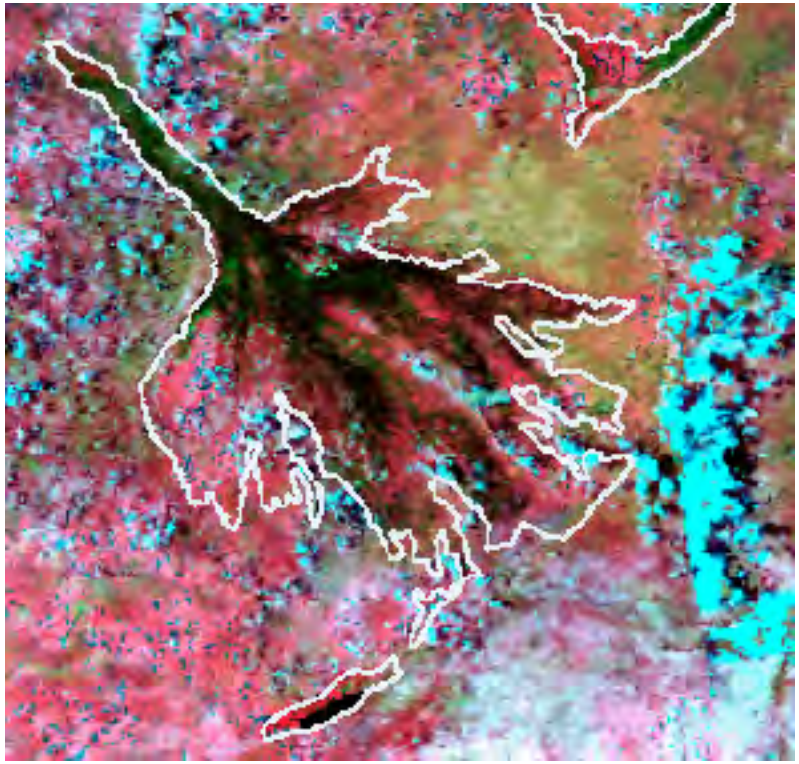

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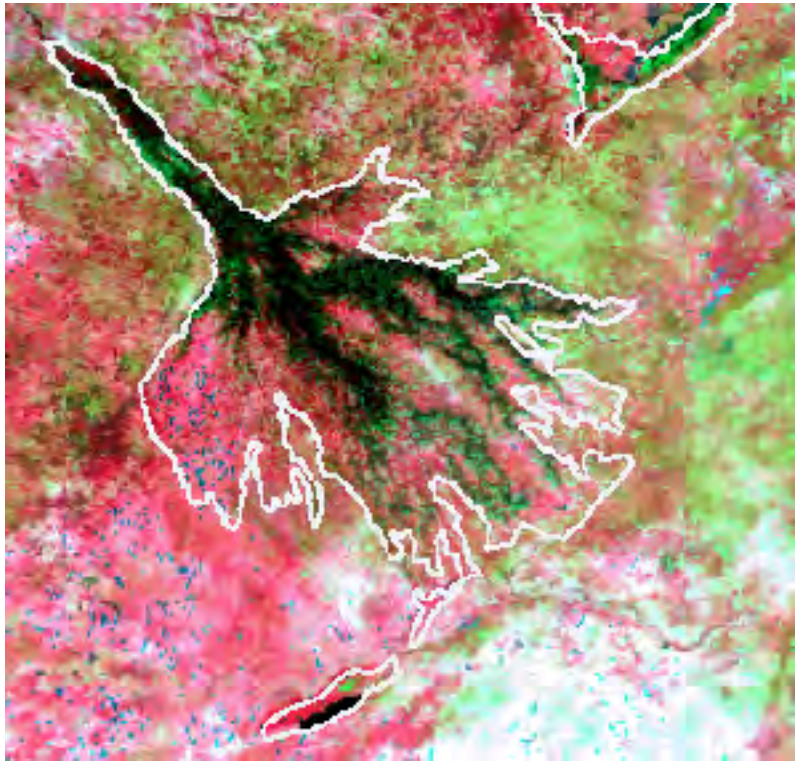

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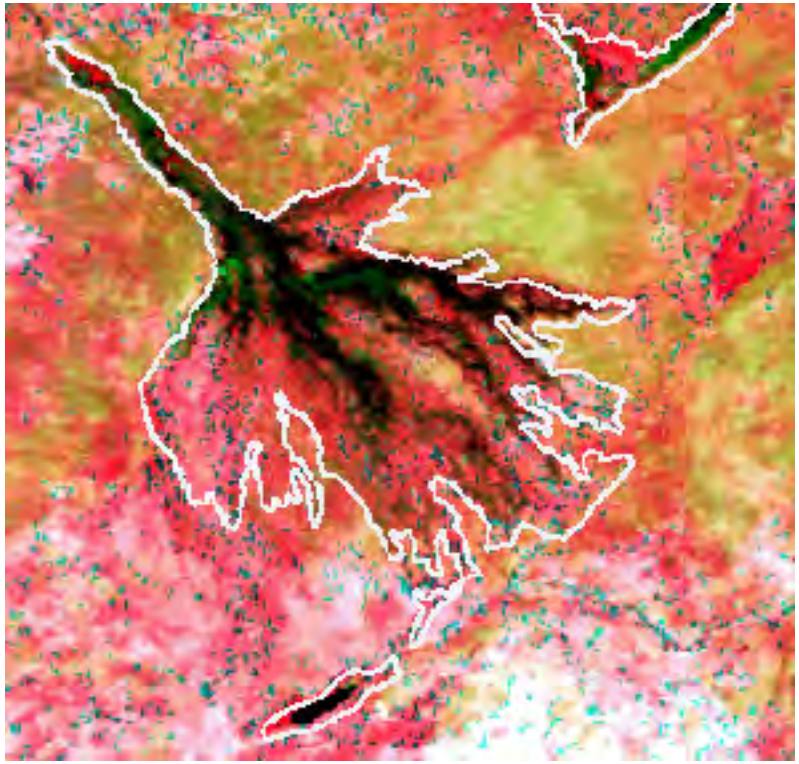

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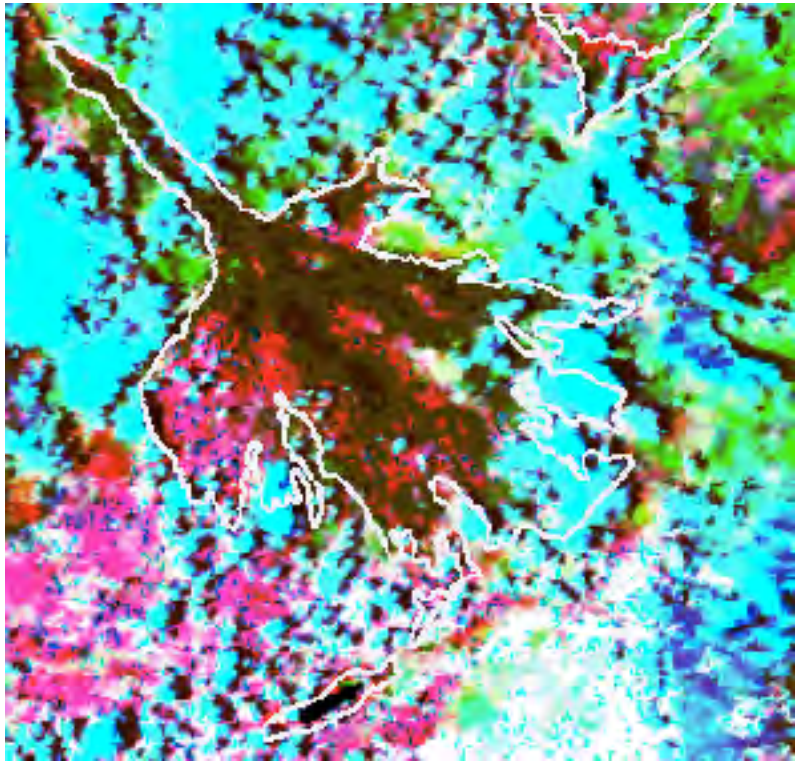


Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

N

100 Km

1992

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite of the

Okavango Delta

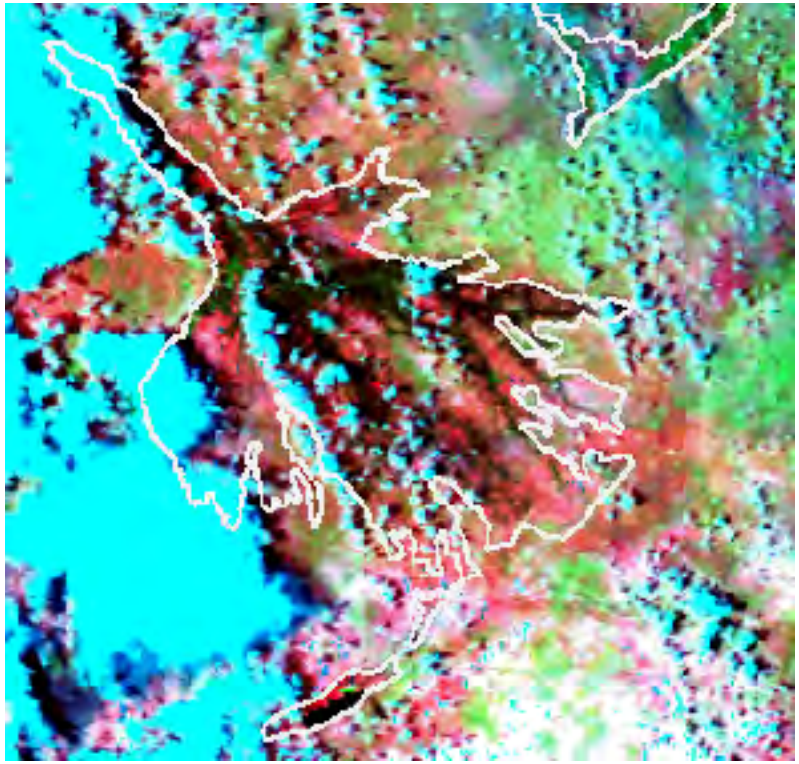
Image composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

N

100 Km

1992

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite of the

Okavango Delta

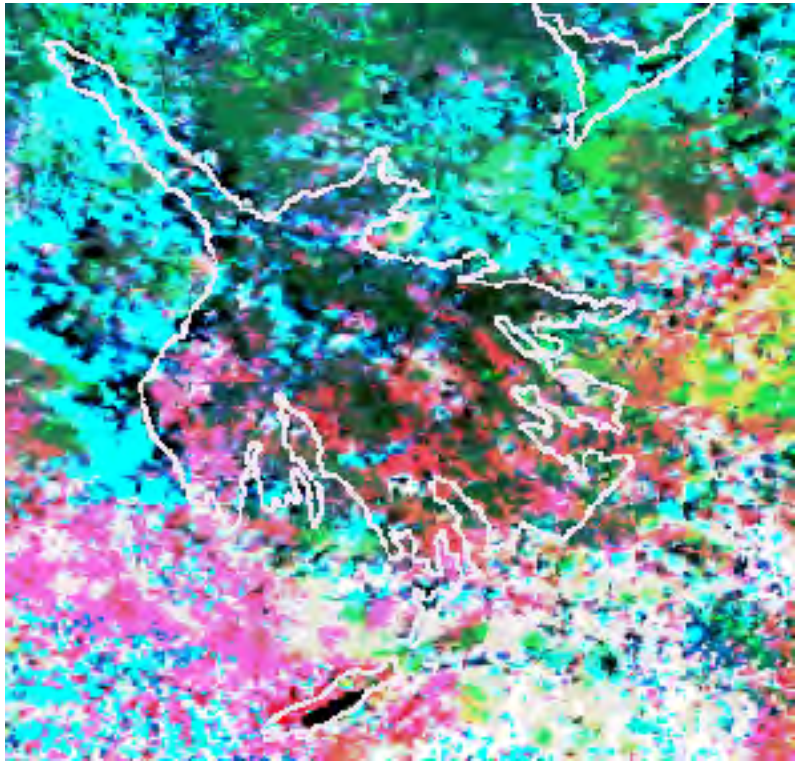
Image composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

N

100 Km

1993

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite of the

Okavango Delta

Image composition:

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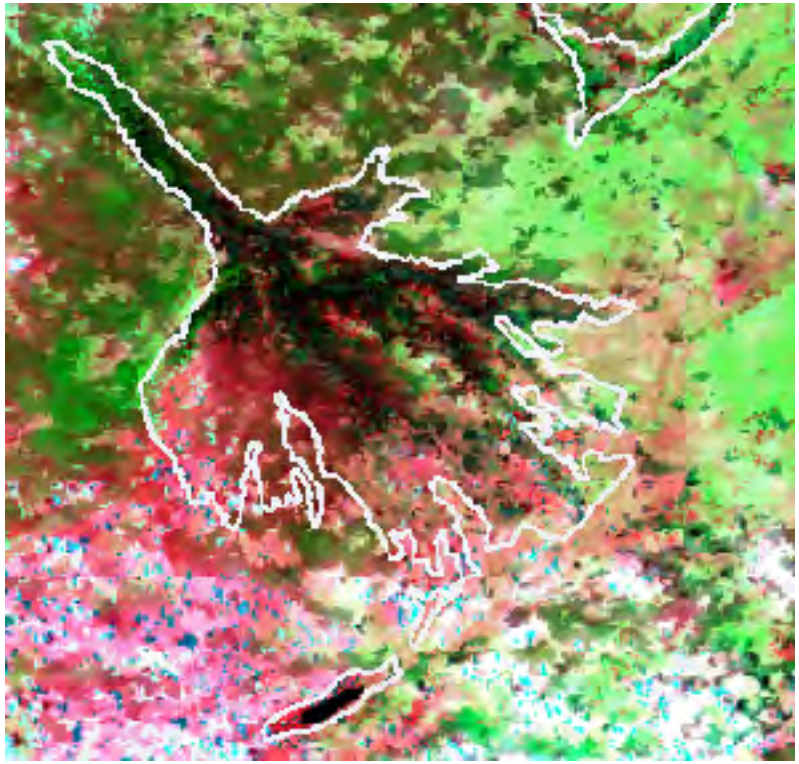
Green = B2

Red = B3

(B = Band)



Band wavelength:

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B2 = Near IR

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100 Km

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Okavango Delta

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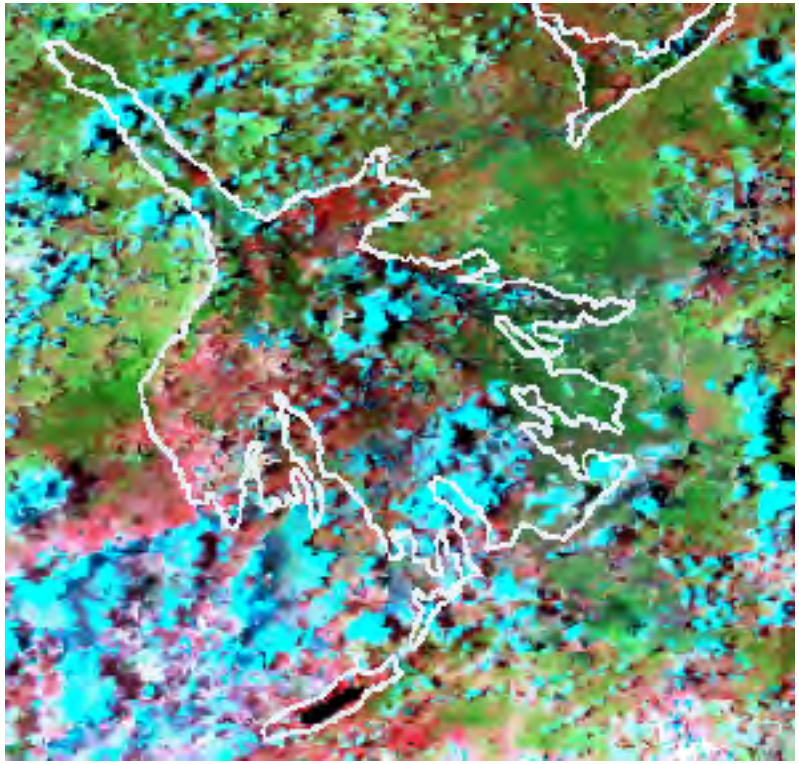
Red = B3

(B = Band)



Band wavelength:

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100 Km

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JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite of the

Okavango Delta

Image composition:

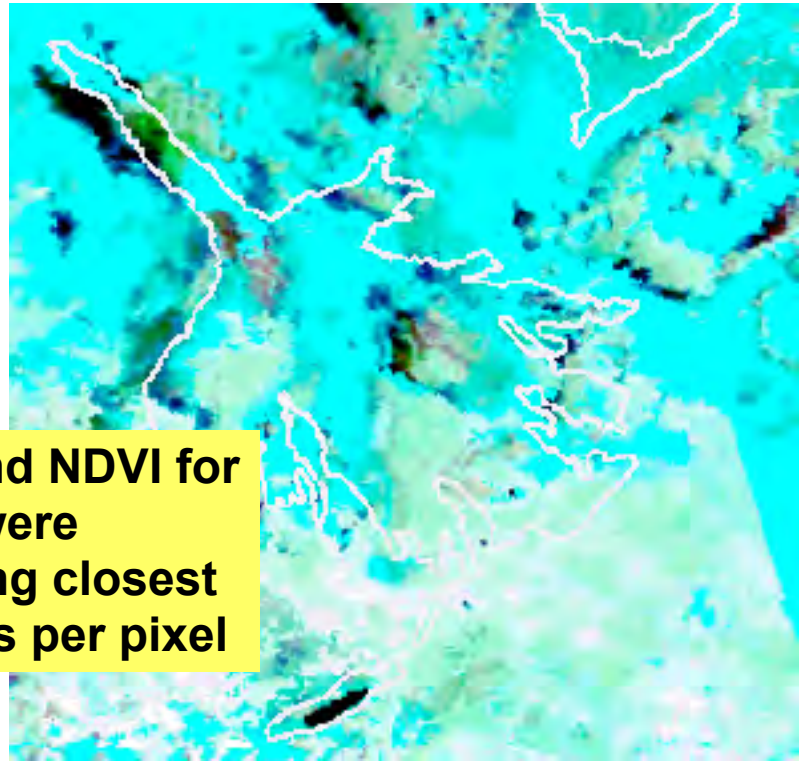
Blue = B1

Green = B2

Red

(B =

Water cover and NDVI for cloudy dates were calculated using closest cloudfree dates per pixel



Band wavelength:

B1 = Green

B2 = Near IR

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100 Km

1993

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NOAA-AVHRR 10 day composite of the

Okavango Delta

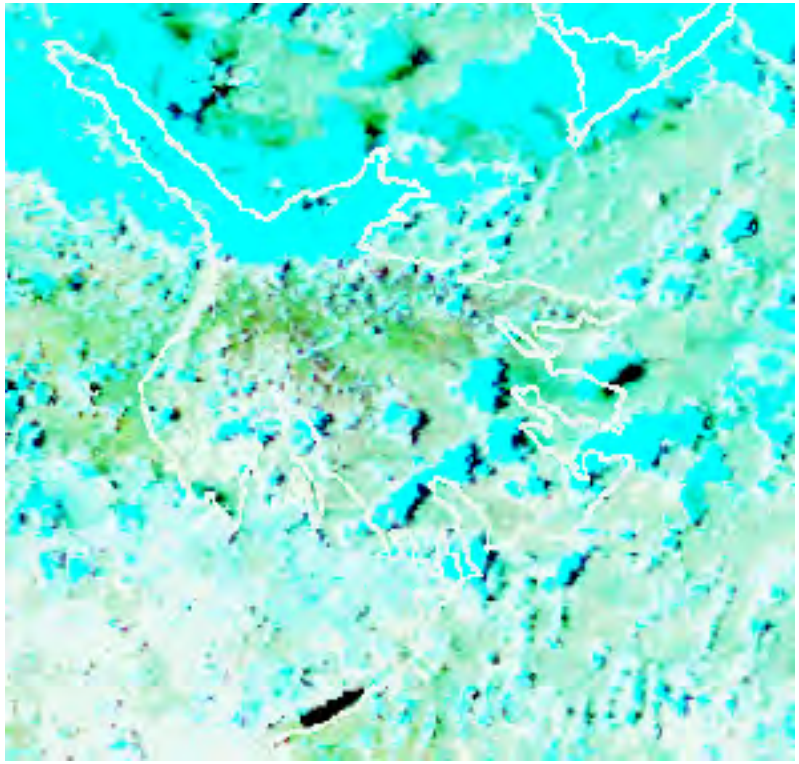
Image composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

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100 Km

1993

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Okavango Delta

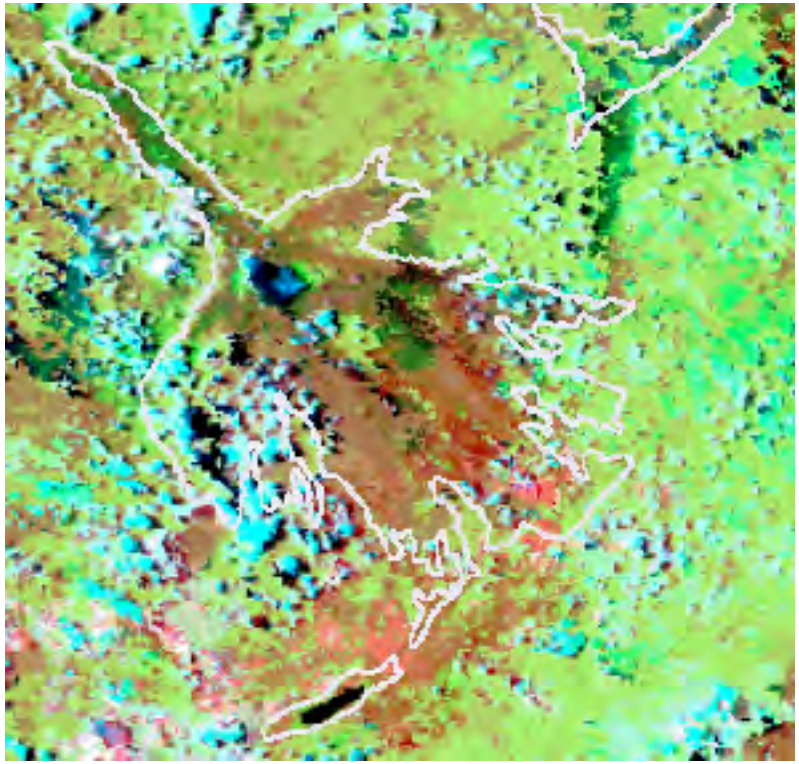
Image composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Band wavelength:

B1 = Green

B2 = Near IR

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100 Km

1993

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

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Image composition:

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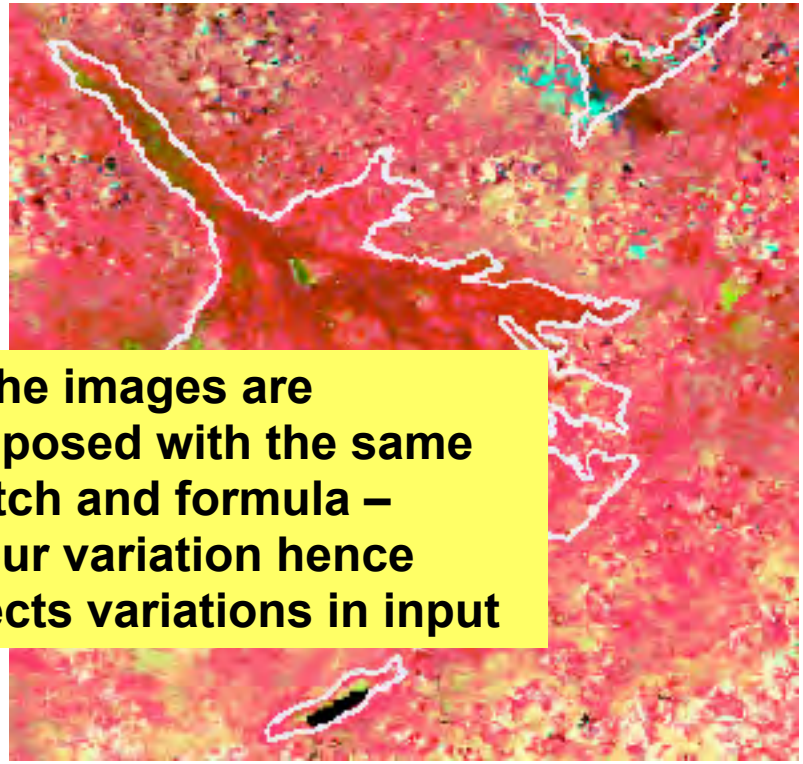

All the images are composed with the same stretch and formula – colour variation hence reflects variations in input

Band wavelength:

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100 Km

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Okavango Delta

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Red = B3

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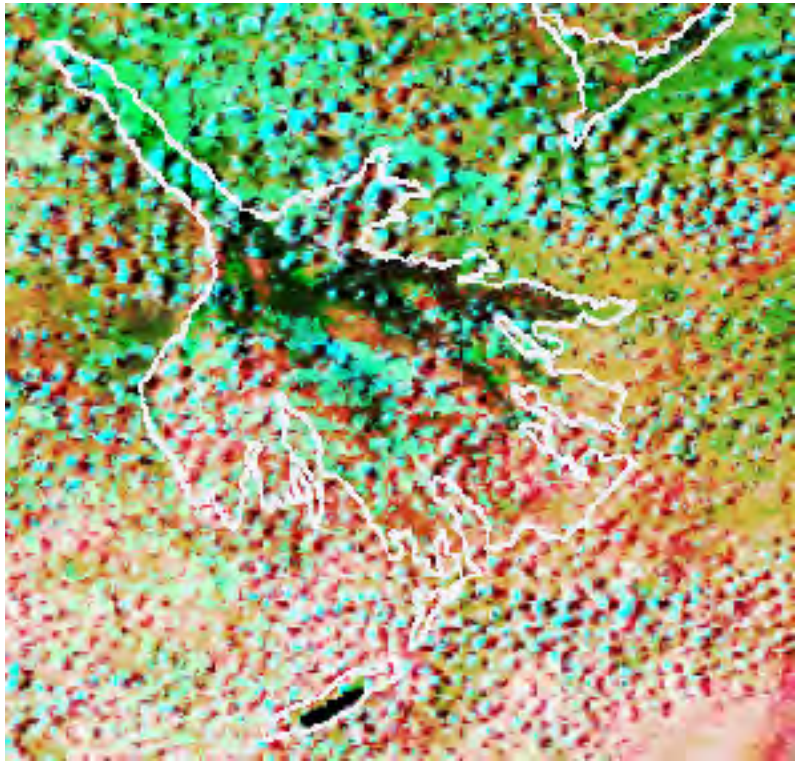

Band wavelength:

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100 Km

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Okavango Delta

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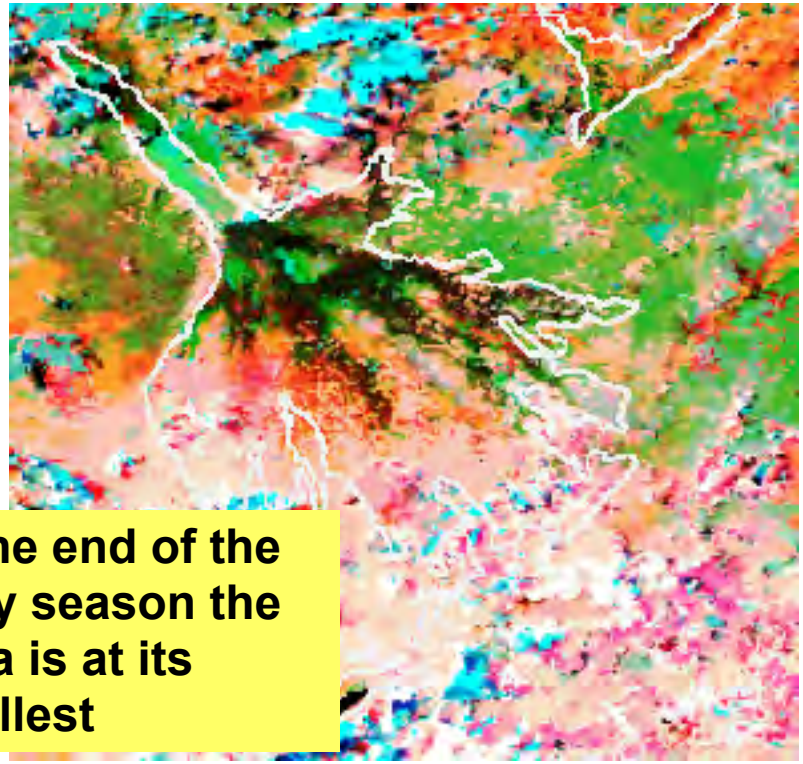

At the end of the rainy season the delta is at its smallest

N

Band wavelength:

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B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

1993

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite of the

Okavango Delta

Image composition:

Blue = B1

Green = B2

Red = B3

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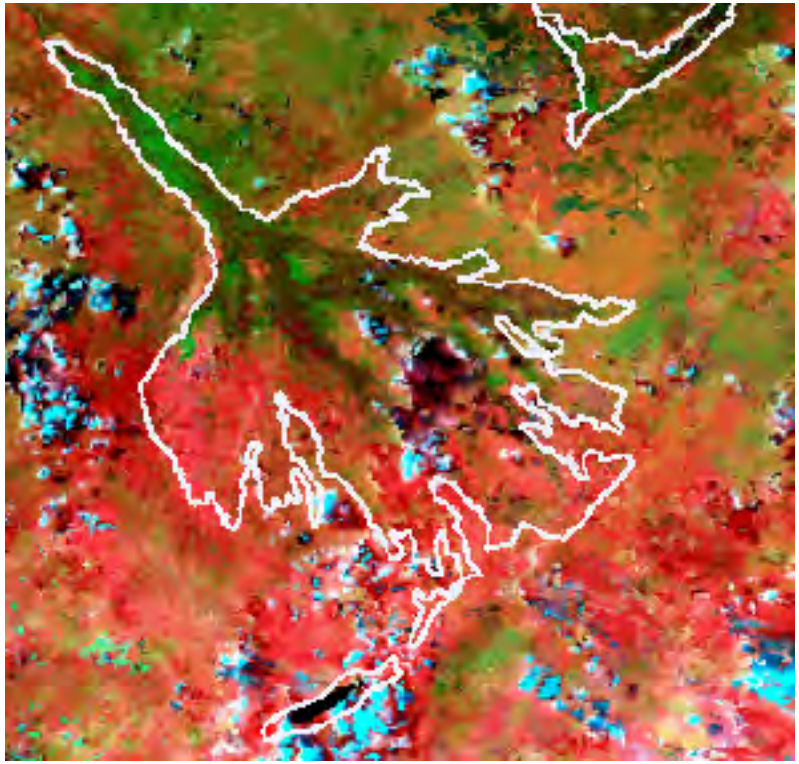

Band wavelength:

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100 Km

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Okavango Delta

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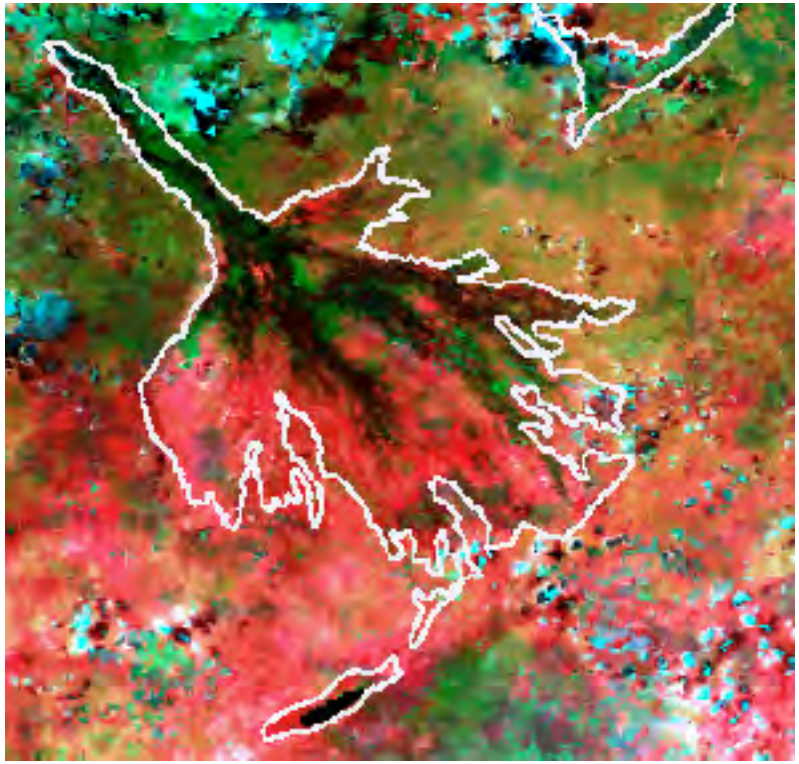

Band wavelength:

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B2 = Near IR

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100 Km

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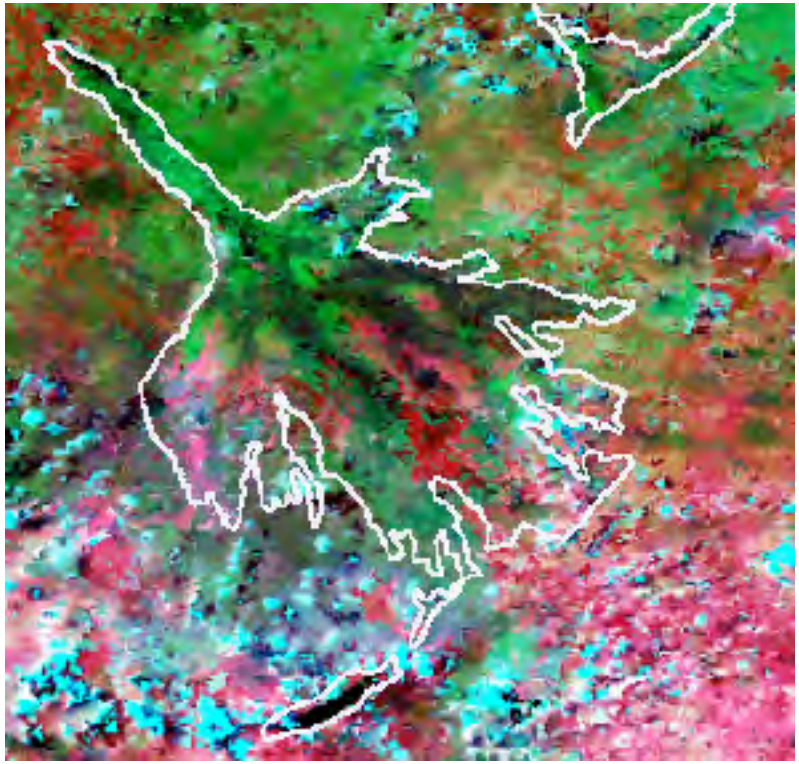

Band wavelength:

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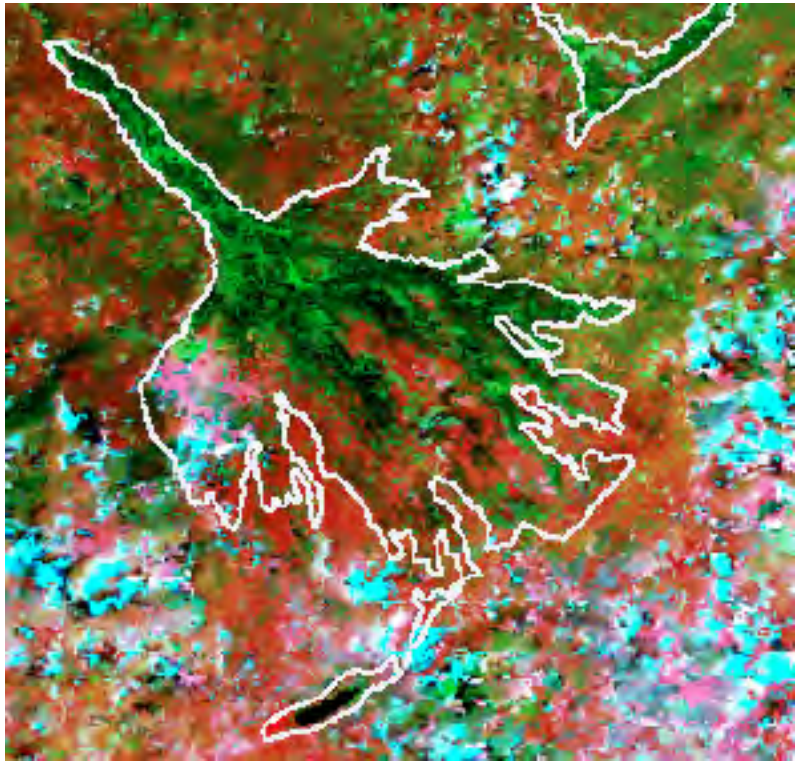

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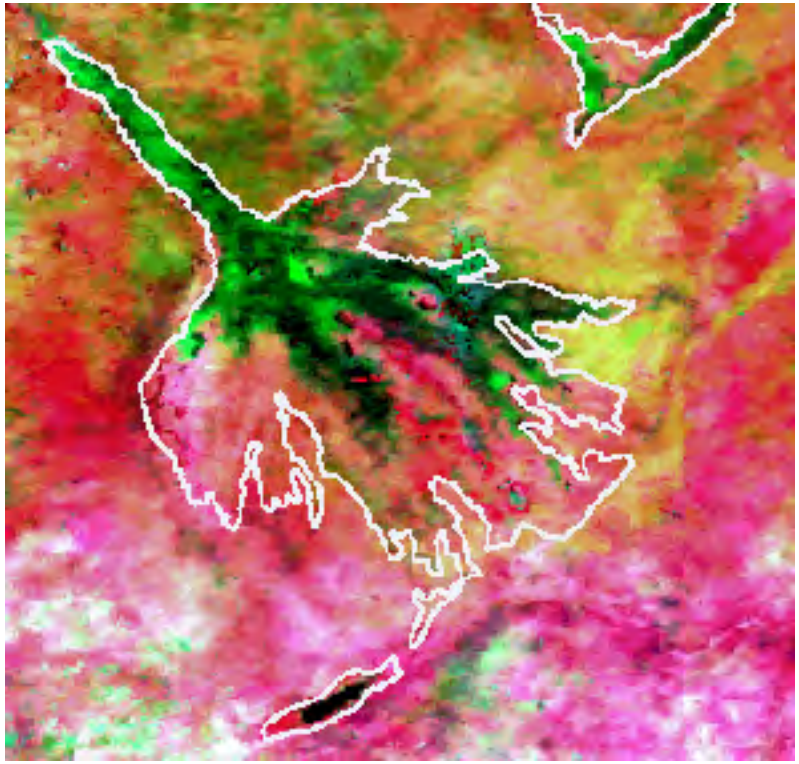

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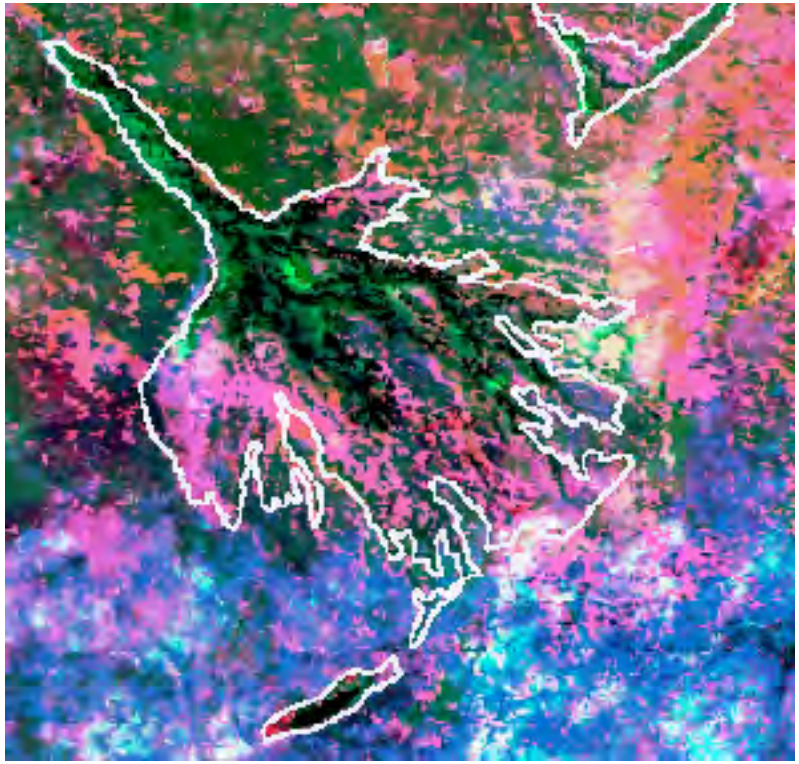

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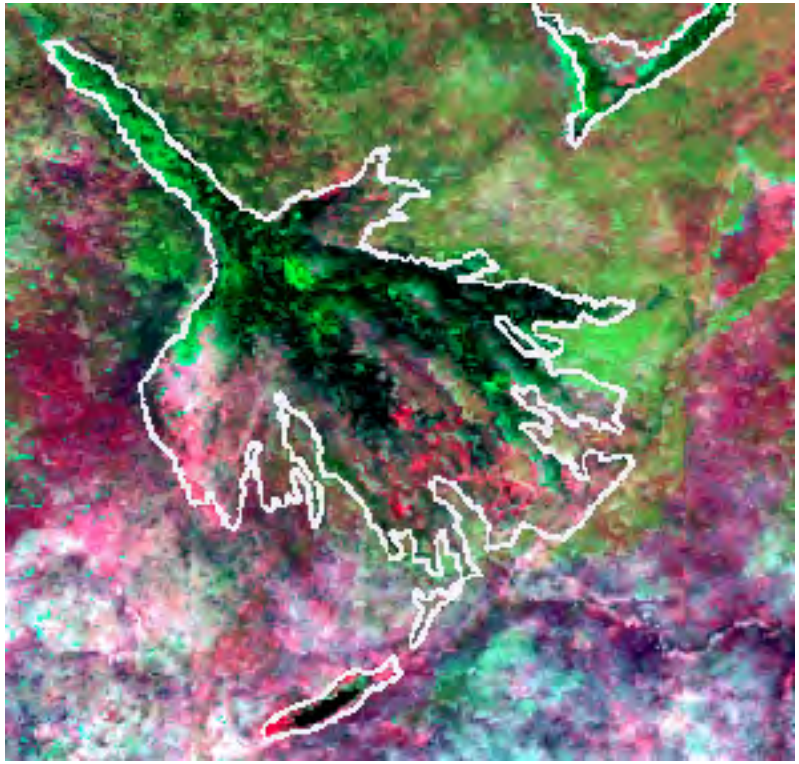

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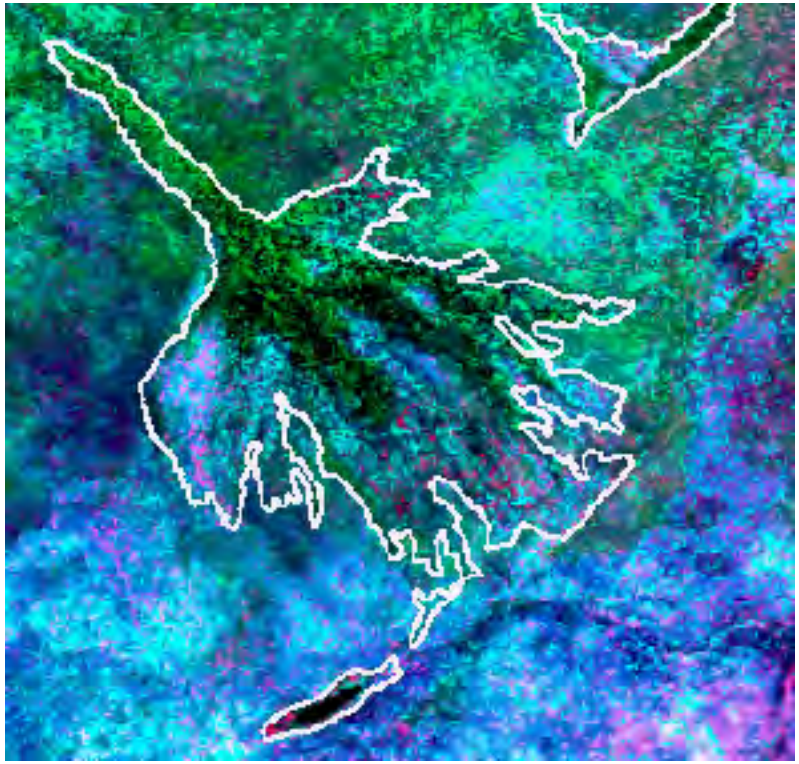

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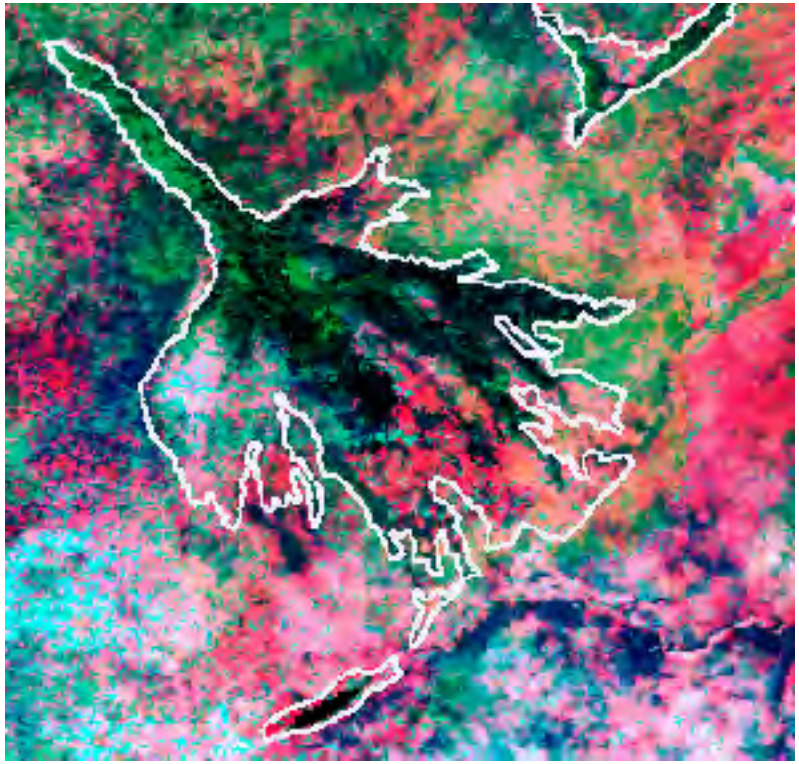

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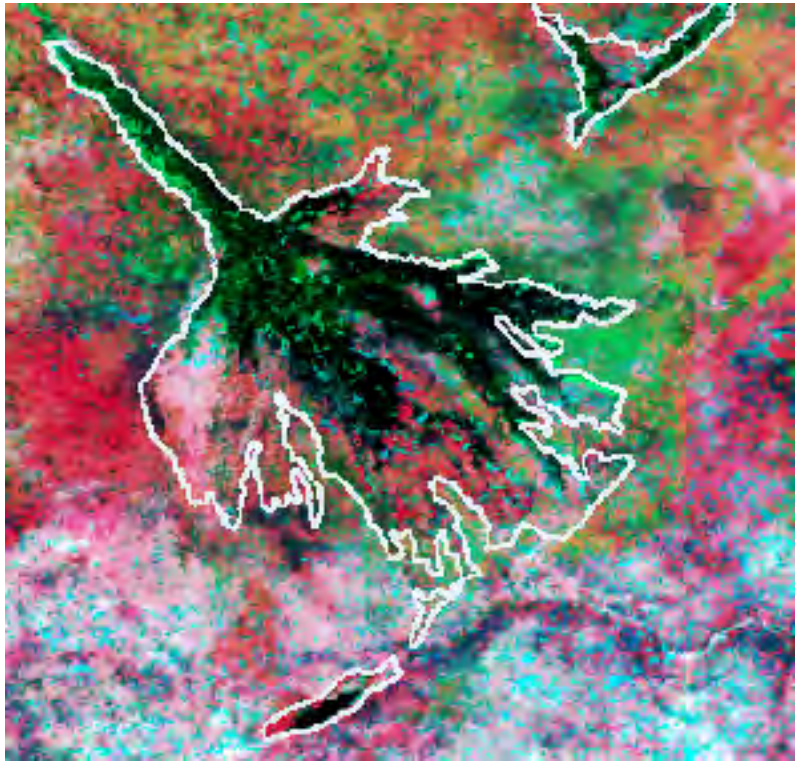

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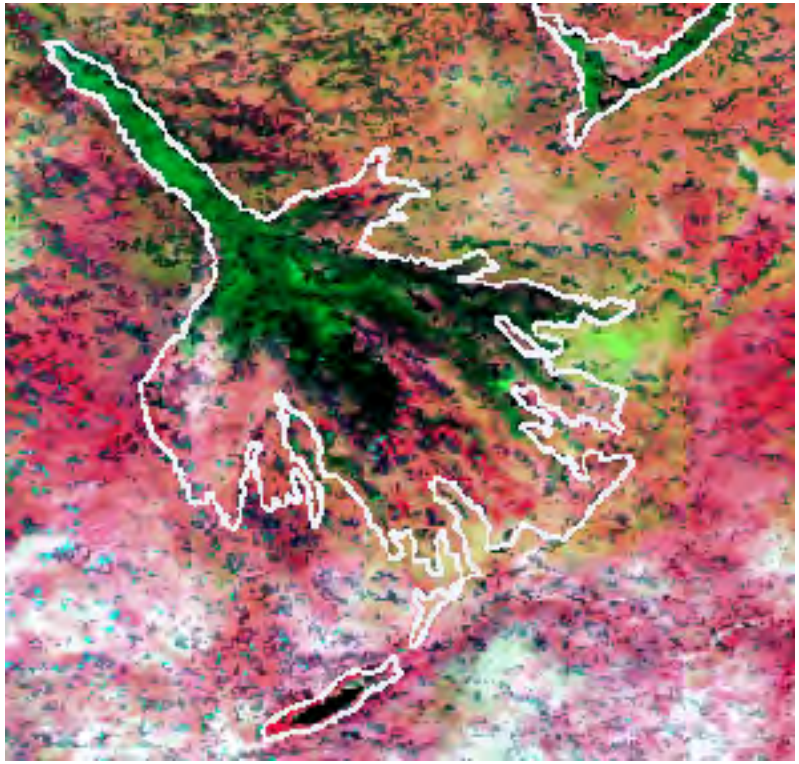

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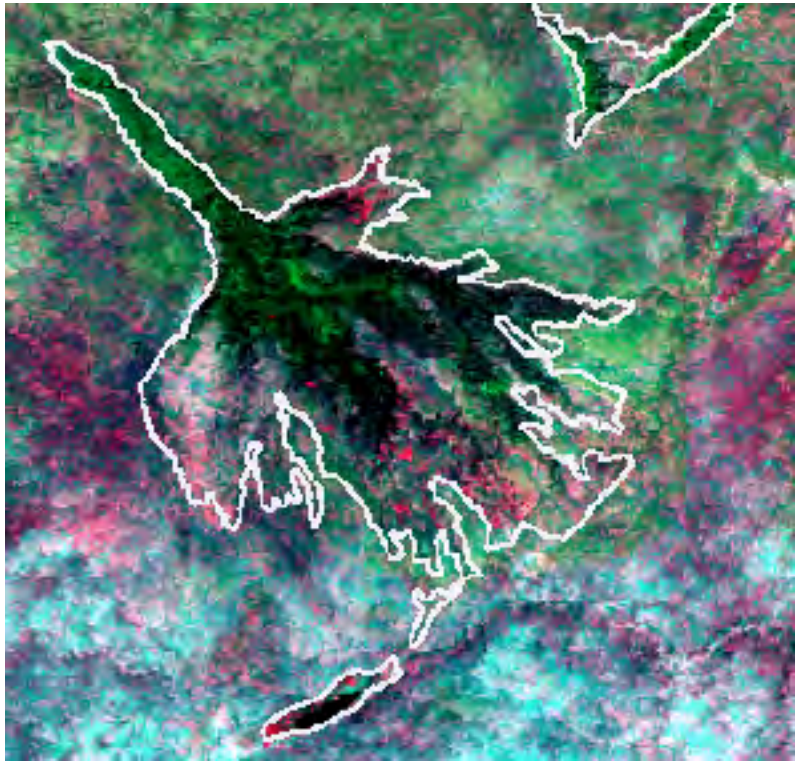

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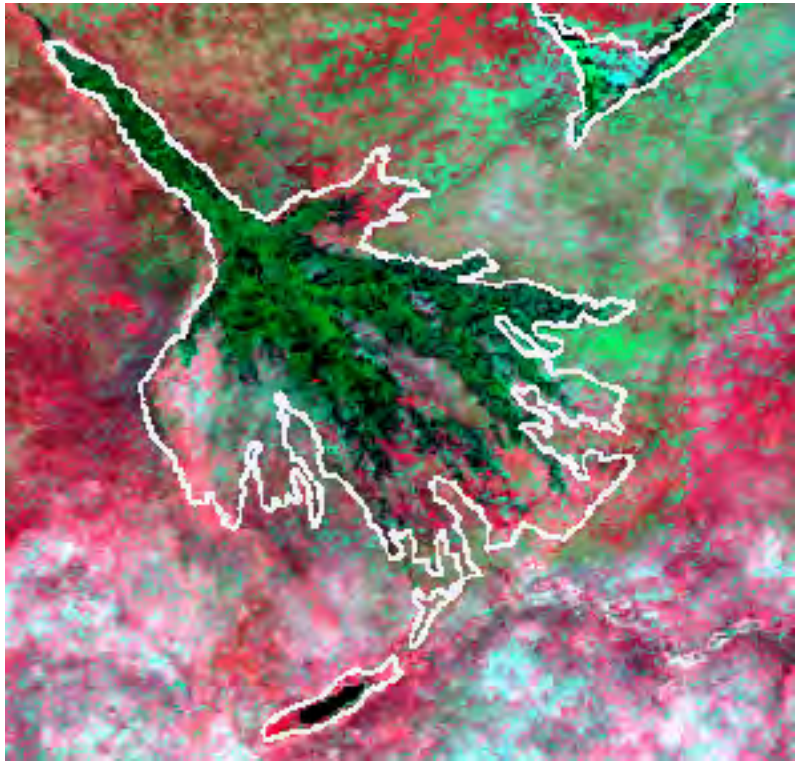

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Okavango Delta

Image composition:

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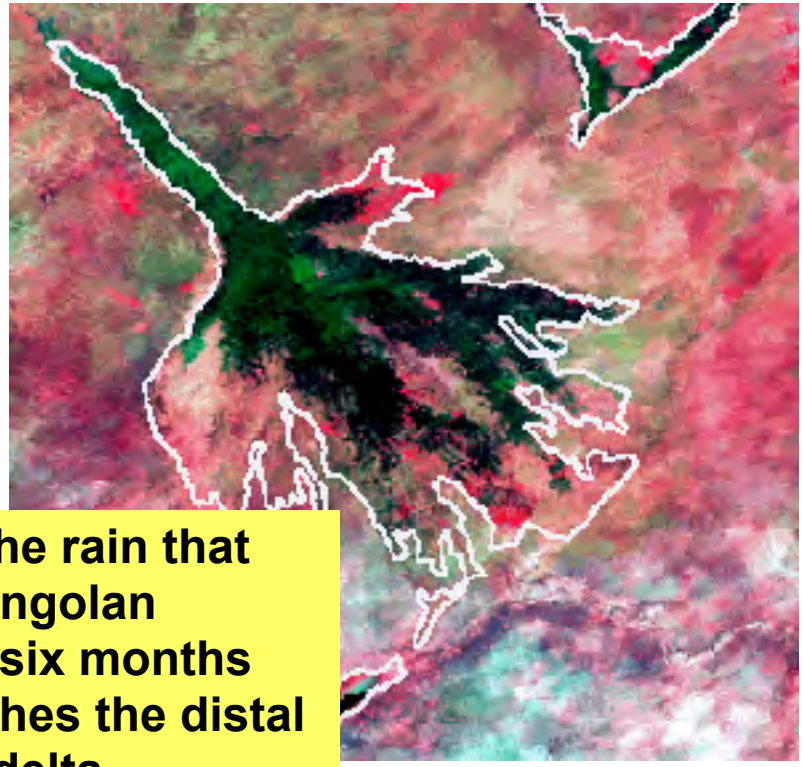

In August the rain that fell in the Angolan mountains six months earlier reaches the distal part of the delta

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100 Km

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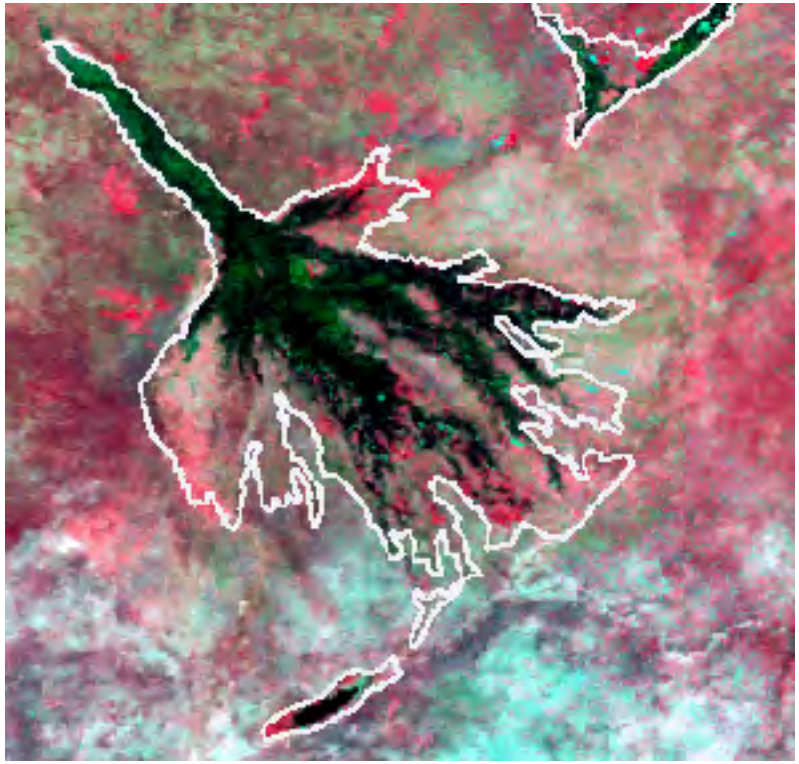

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NOAA-AVHRR 10 day composite of the

Okavango Delta

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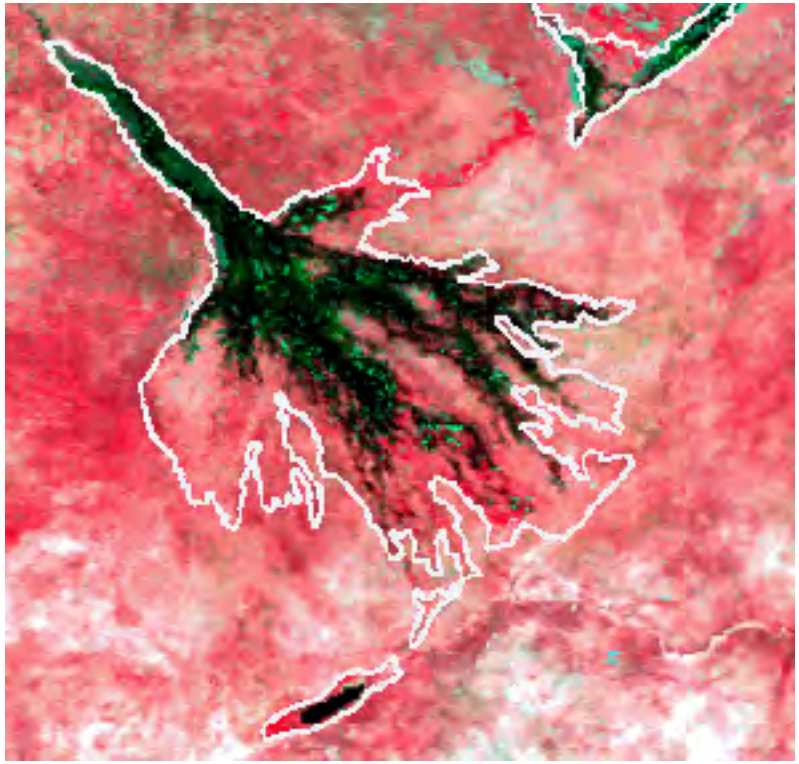

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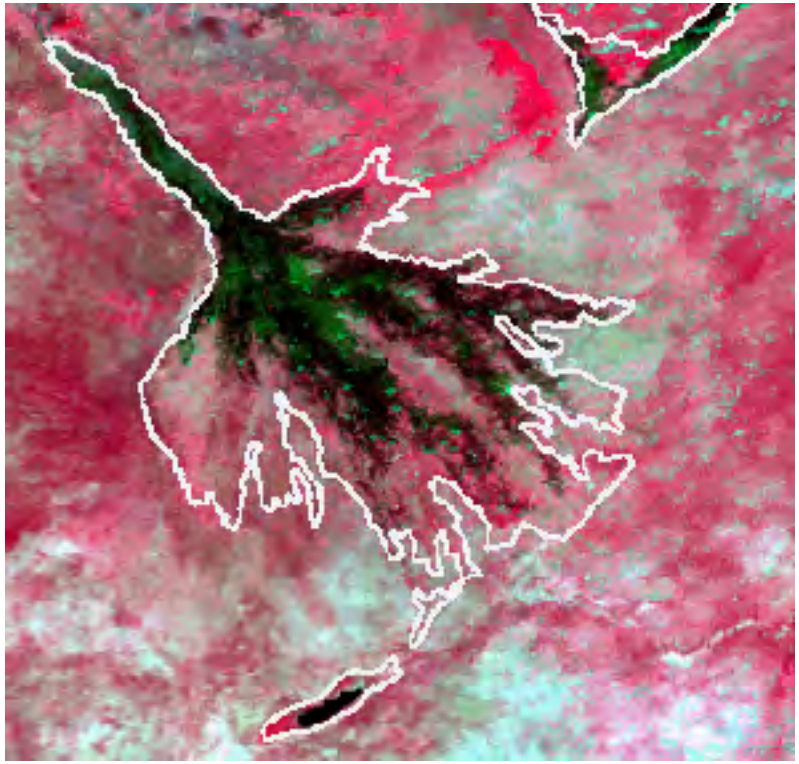

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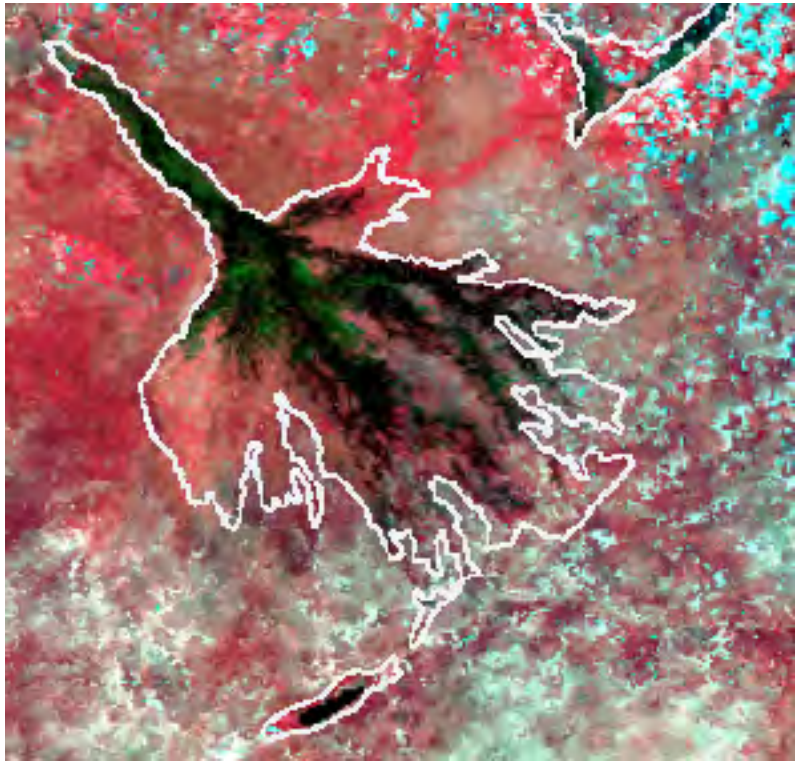

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100 Km

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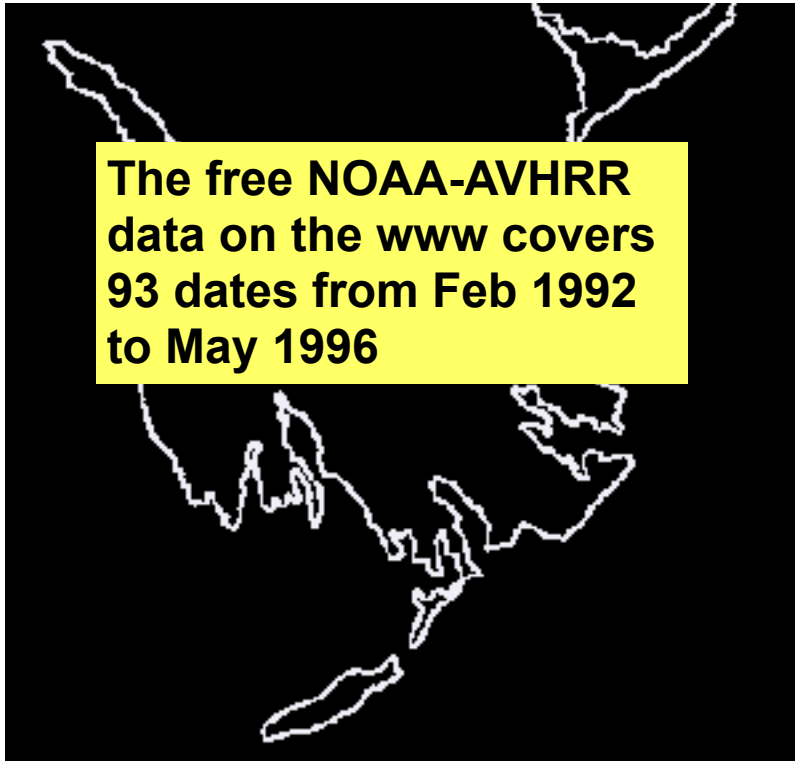

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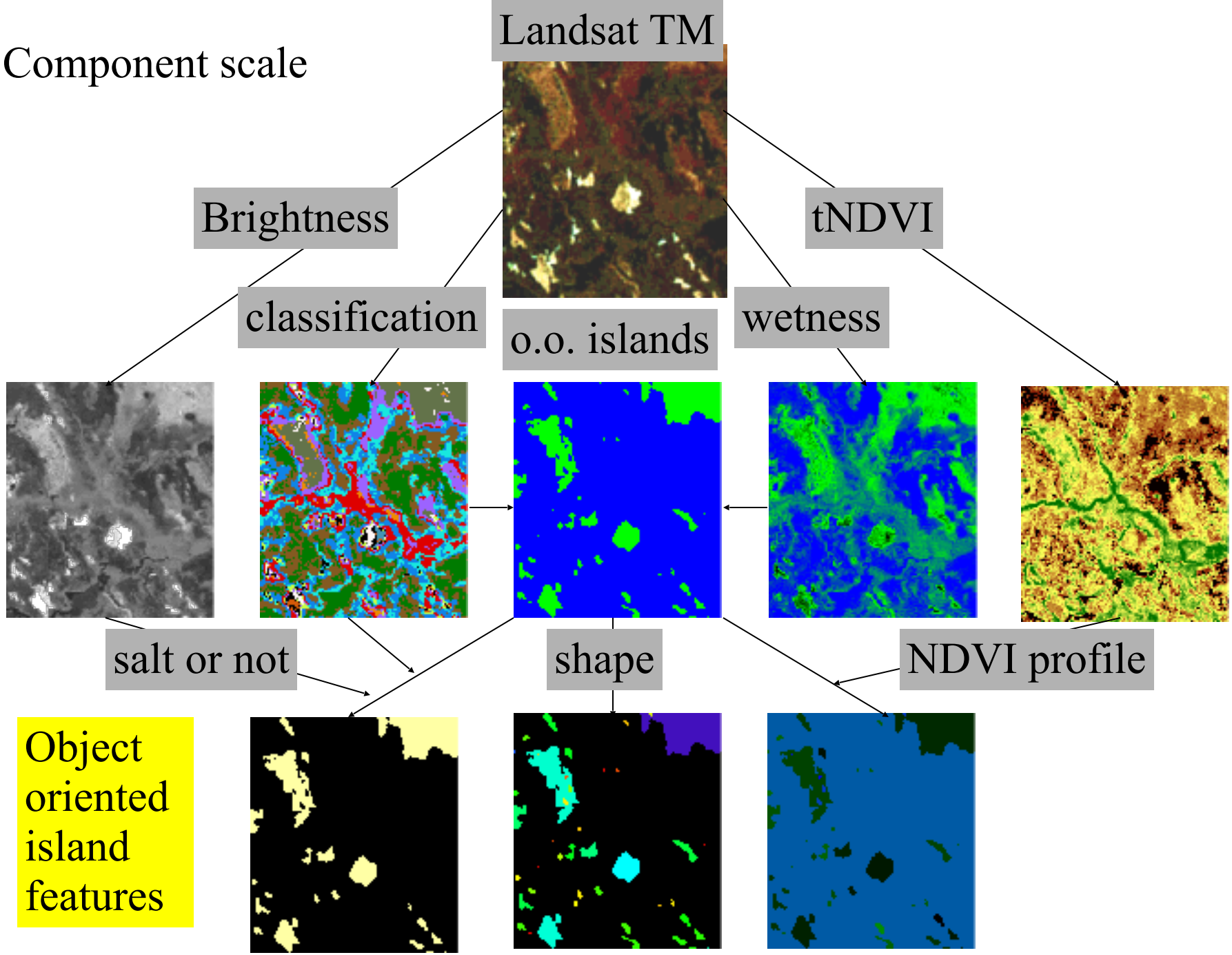
N

100 Km

1994 – NO DATA

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

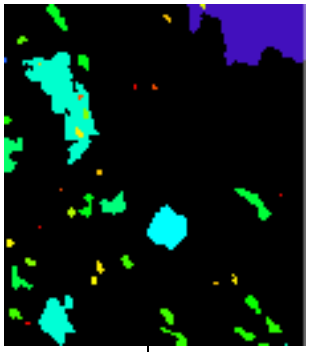
Data enhancement & interpretation


Component scale
Landsat TM
Brightness
classification
o.o. islands
wetness
tNDVI
salt or not
shape
NDVI profile
Object oriented island features

Object oriented island features

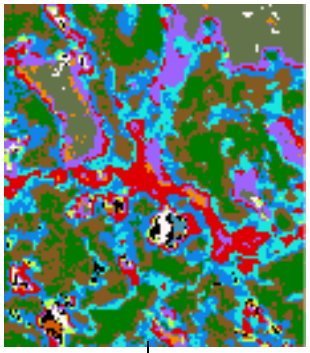
salt or not

shape

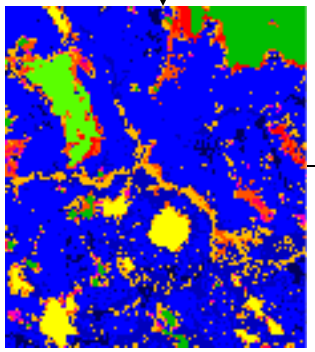


NDVI profile

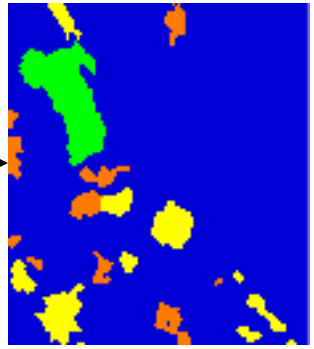
classification



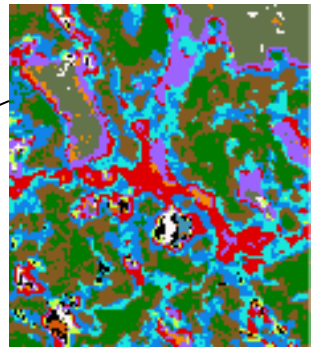
Rule based (if .... then ....) classification

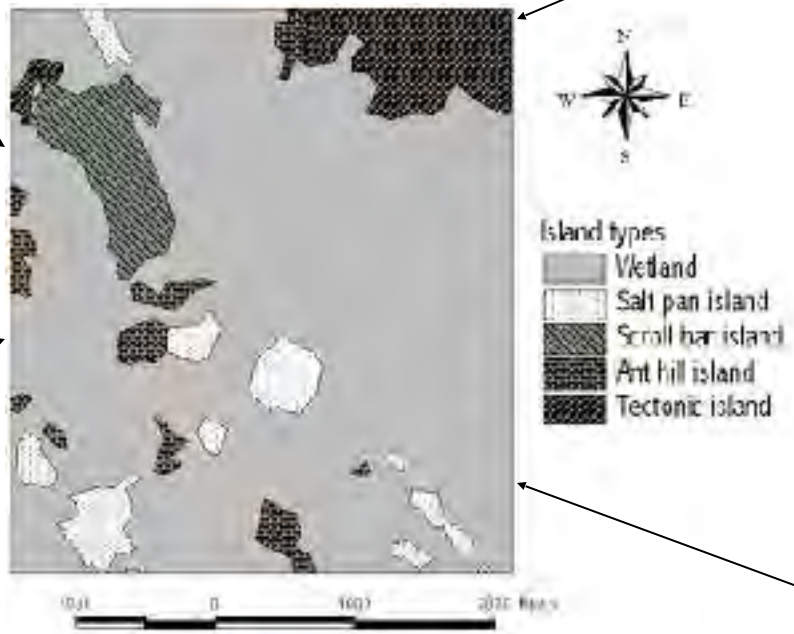


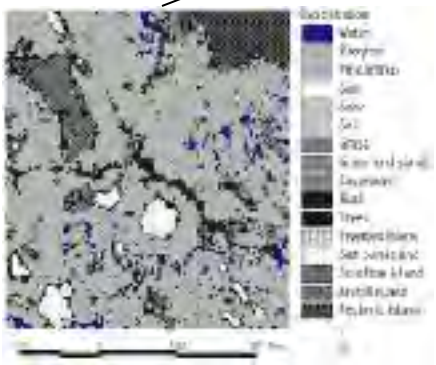
island generalisation

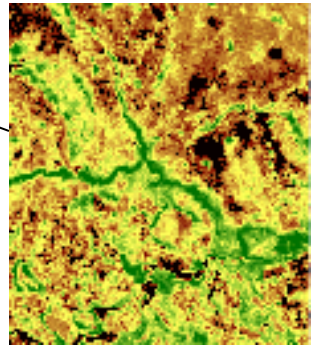


Object oriented database of the Delta islands and their characteristics









NOAA-AVHRR 10 day composite in ”true colours” of the

Okavango Delta

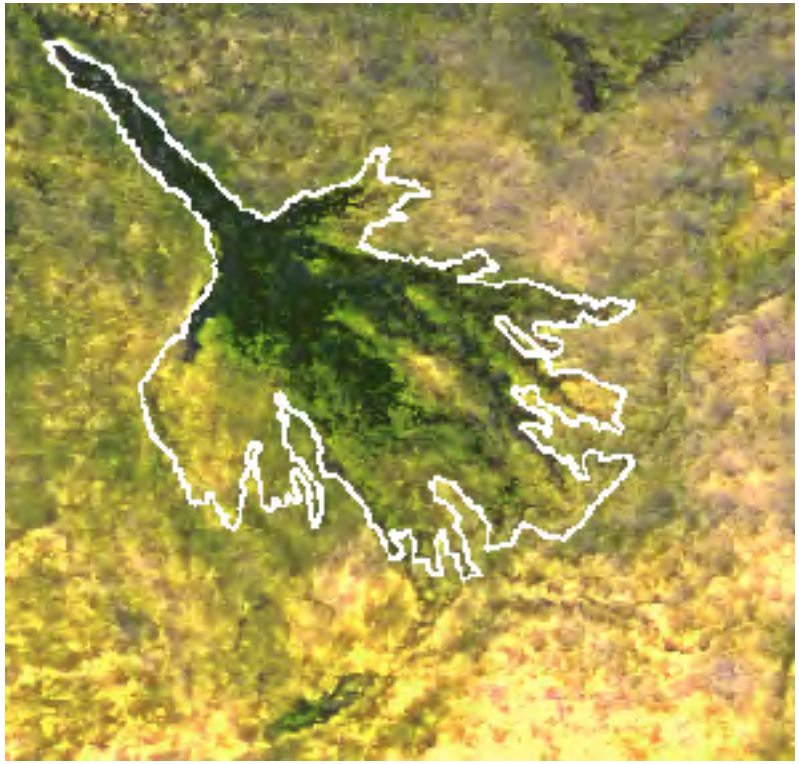
Image composition:

Blue = B1

Green = B1+B3

Red = B2

(B = Band)



Band wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

N

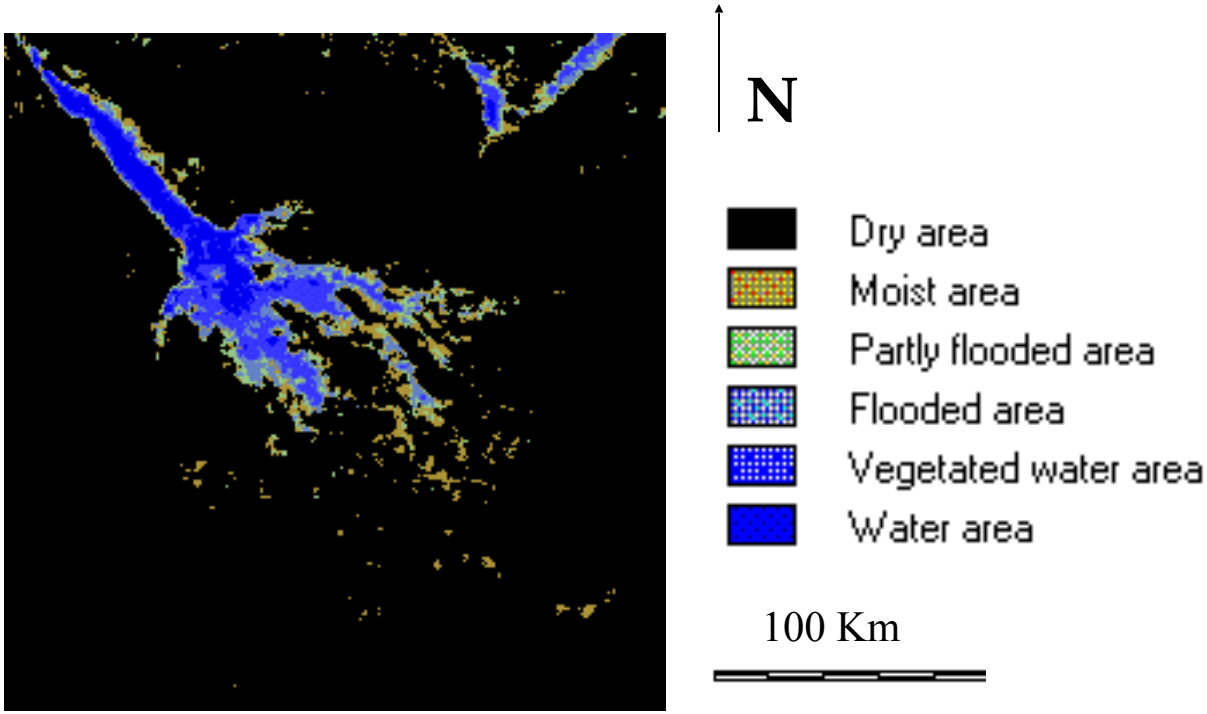
100 Km

1992

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite derived water mask

Okavango Delta



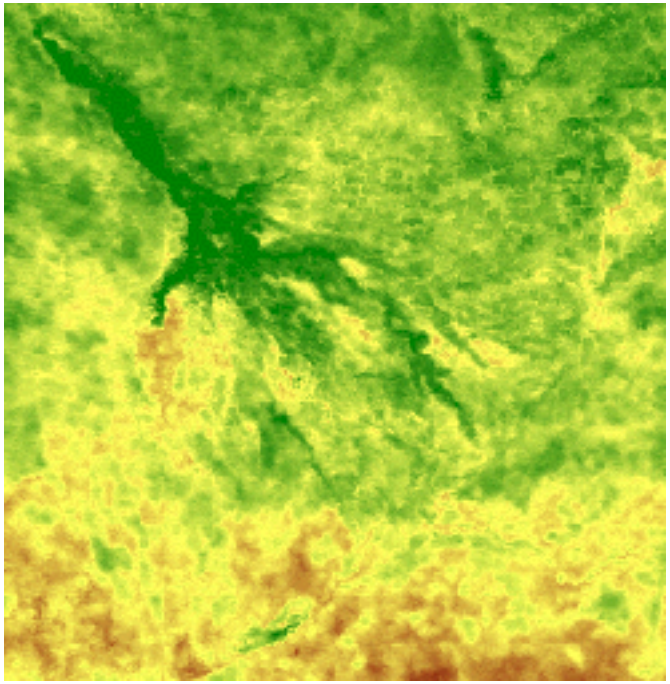
1992

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

NOAA-AVHRR 10 day composite NDVI

Okavango Delta

0, no veg.
50, sparse veg.
100, little veg.
150, intermed. veg
200, dense veg.
250, very dense veg.



$$NDVI = \frac{NIR-VIS}{NIR+VIS}$$

NIR = band 2
VIS = band 1

N

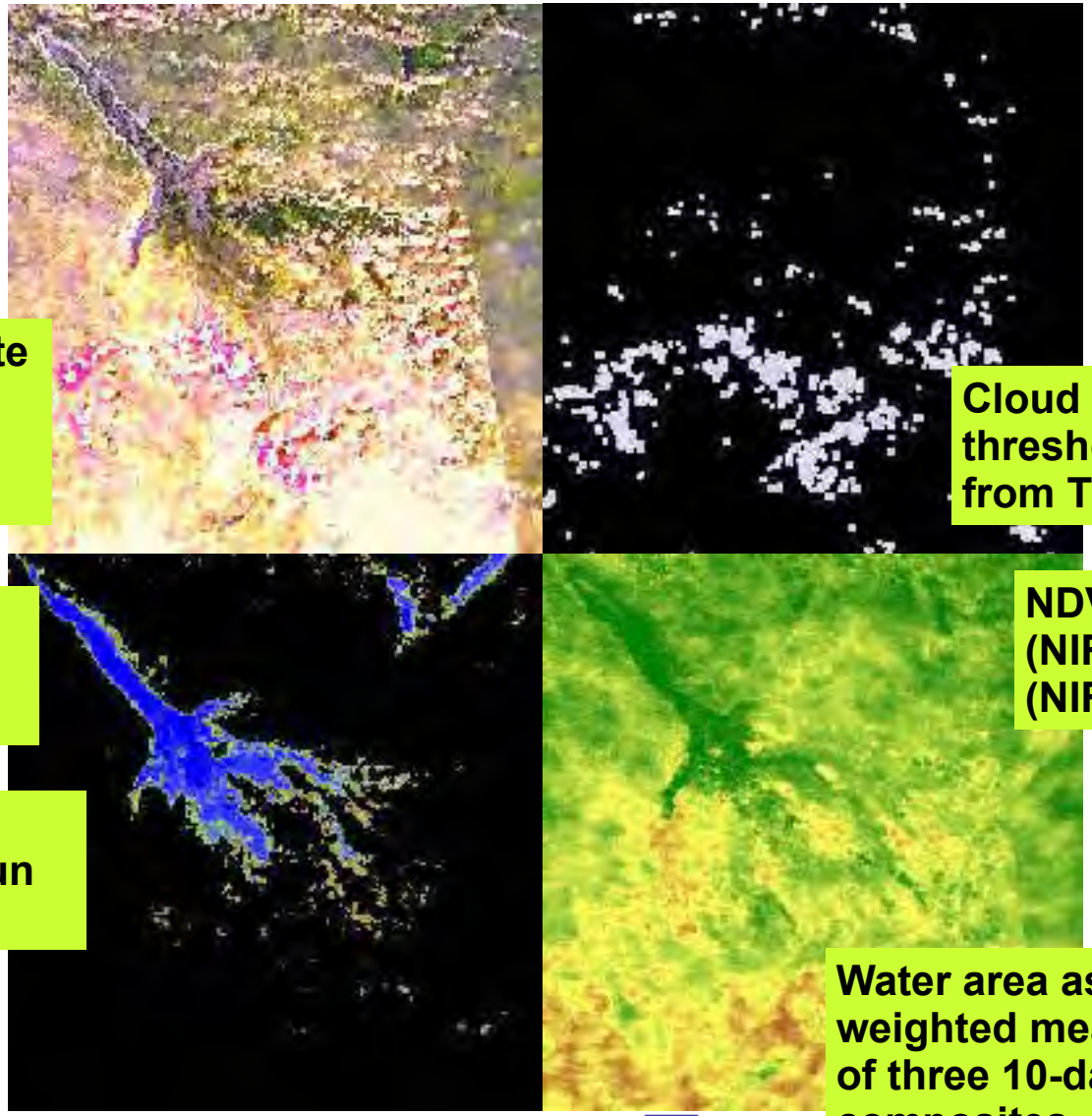
100 km

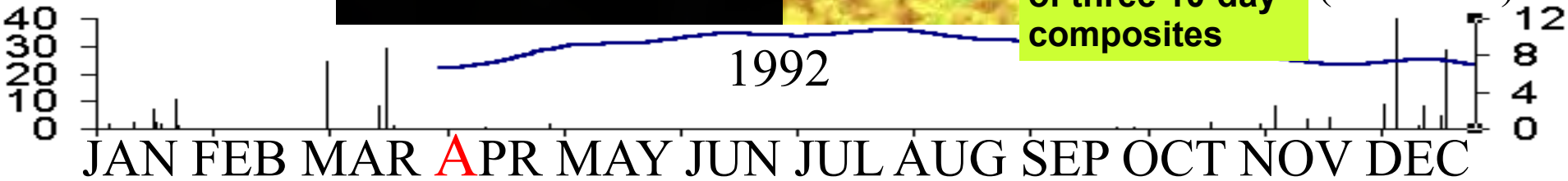
Precipitation in Maun (mm)

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Okavango Delta, Botswana

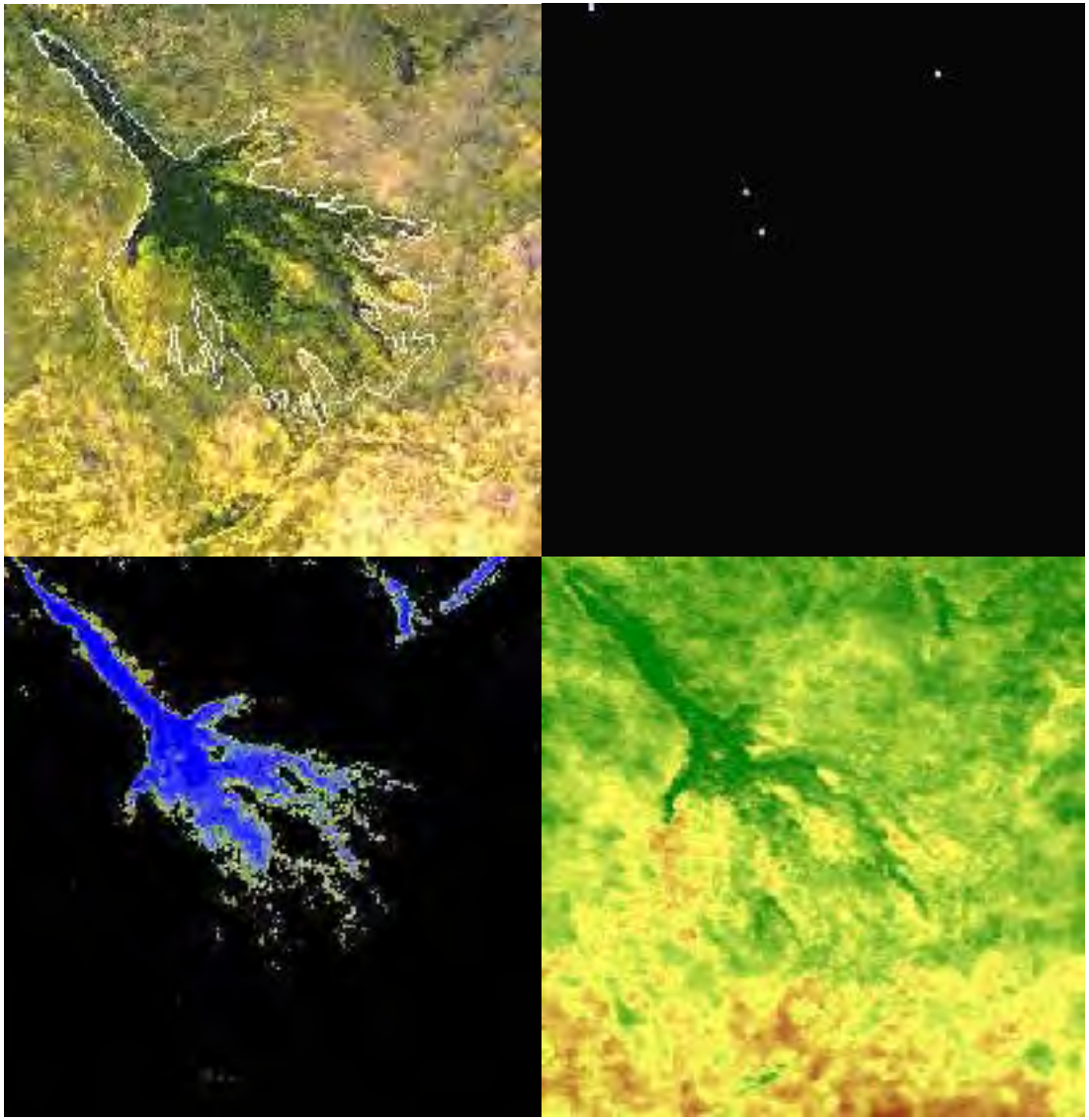
NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images



True colours

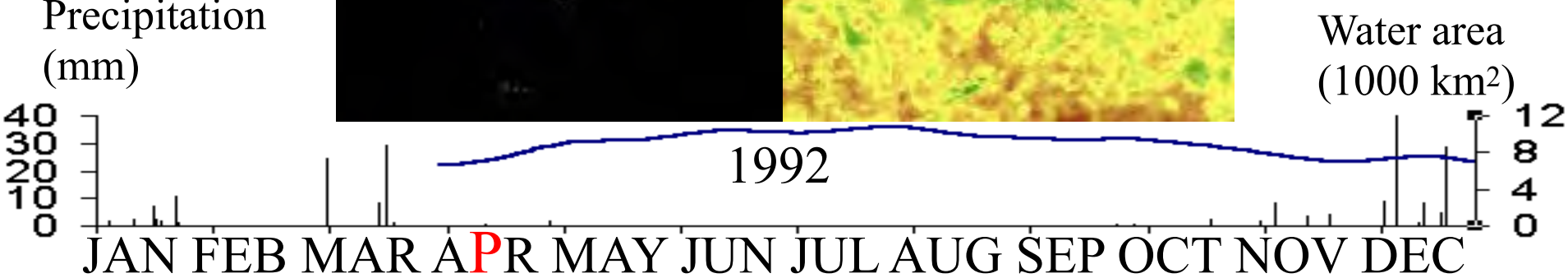
Clouds

Water

NDVI

N

100 Km



Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

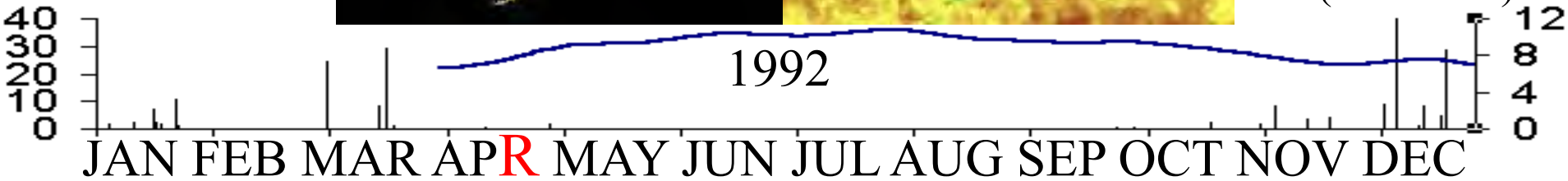
NDVI

N

100 Km

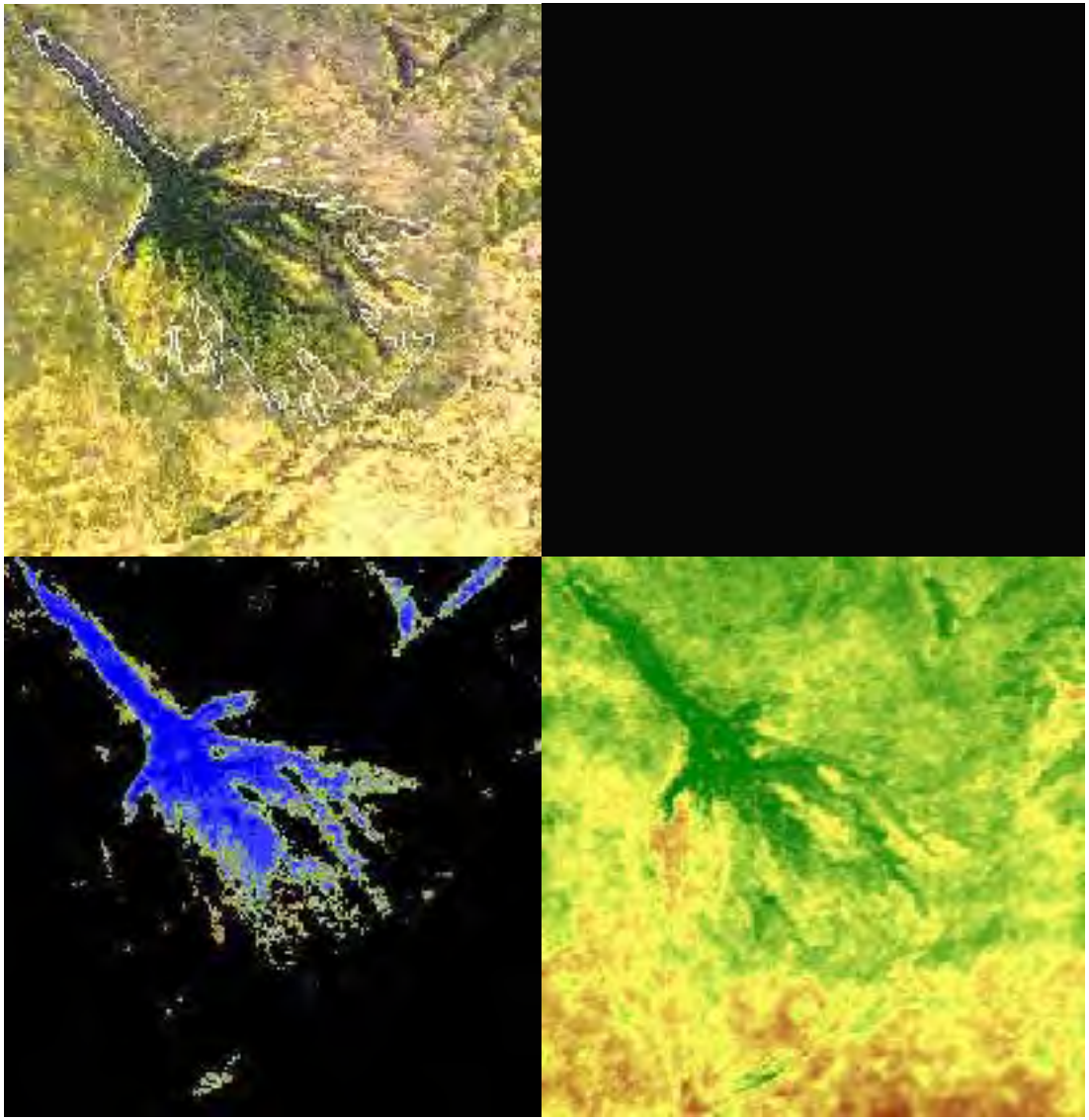
Precipitation (mm)

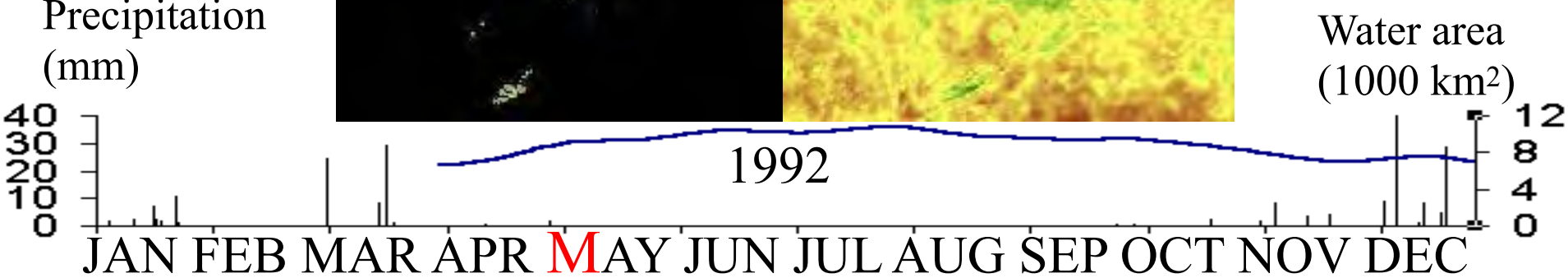
Water area (1000 km²)



Okavango Delta, Botswana

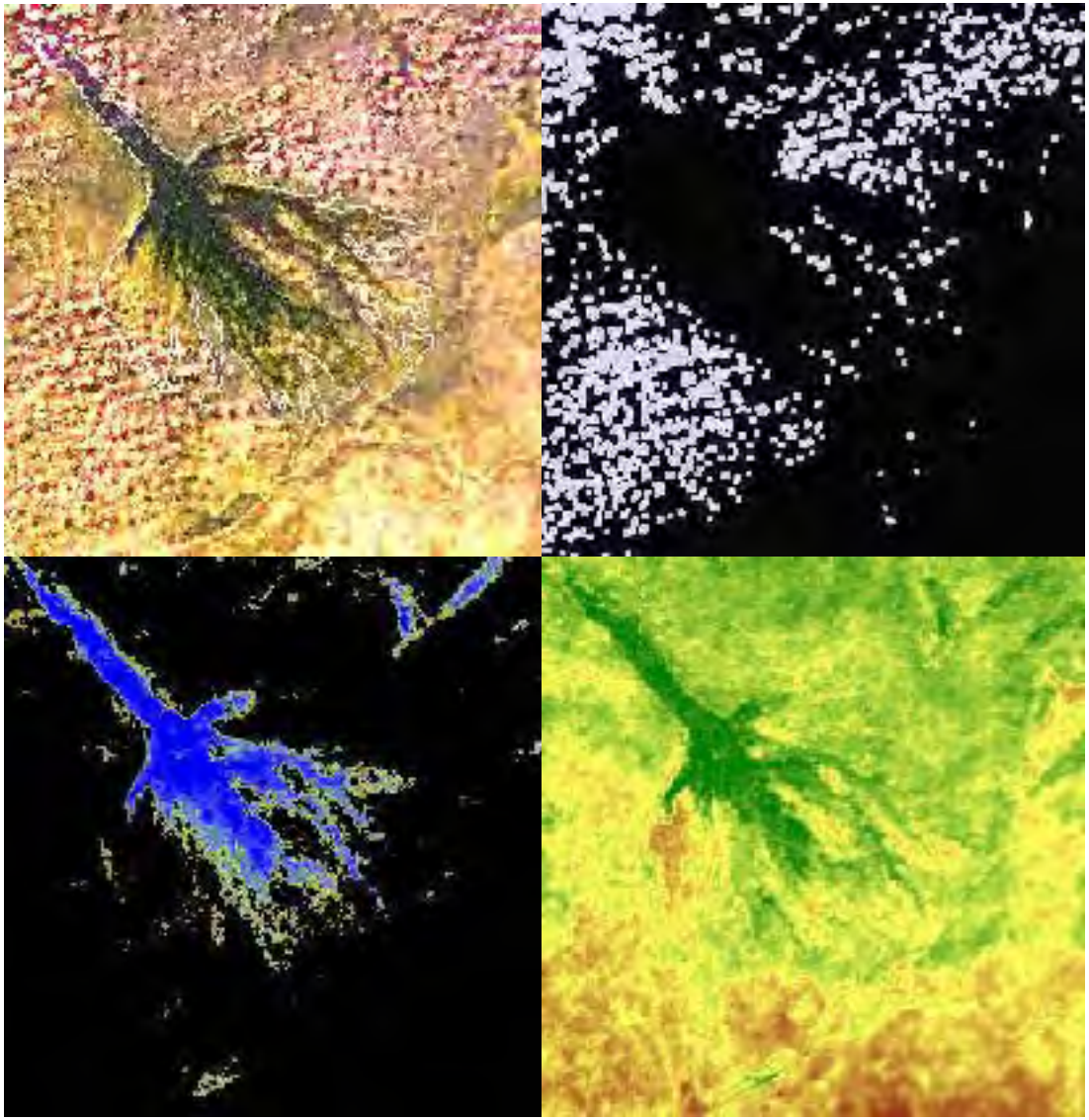
NOAA-AVHRR Images

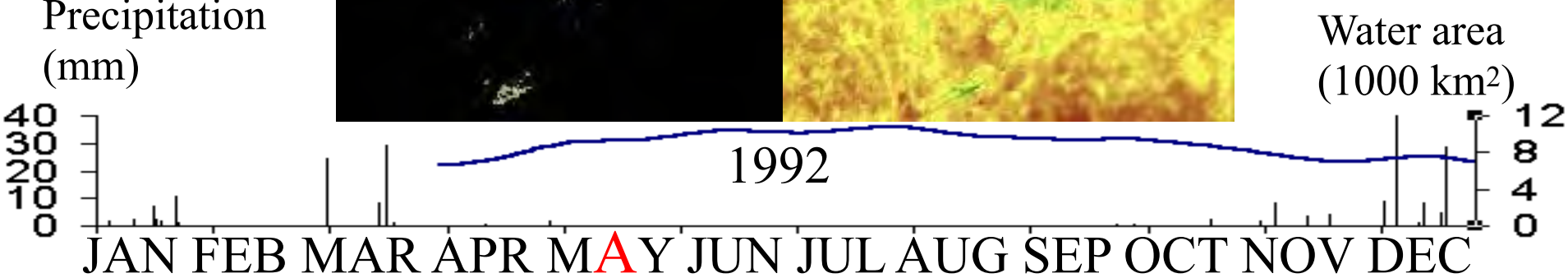




Okavango Delta, Botswana

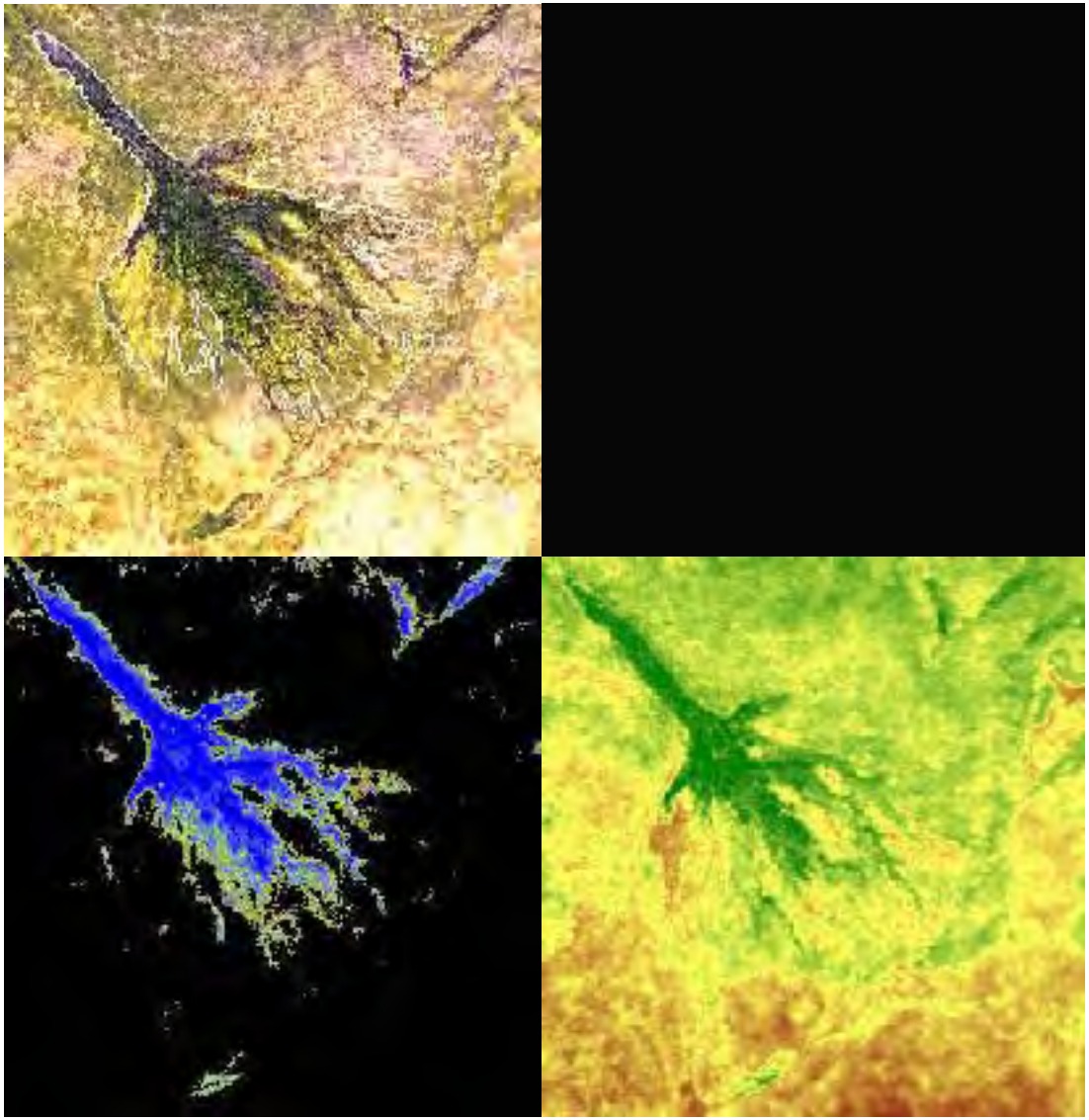
NOAA-AVHRR Images

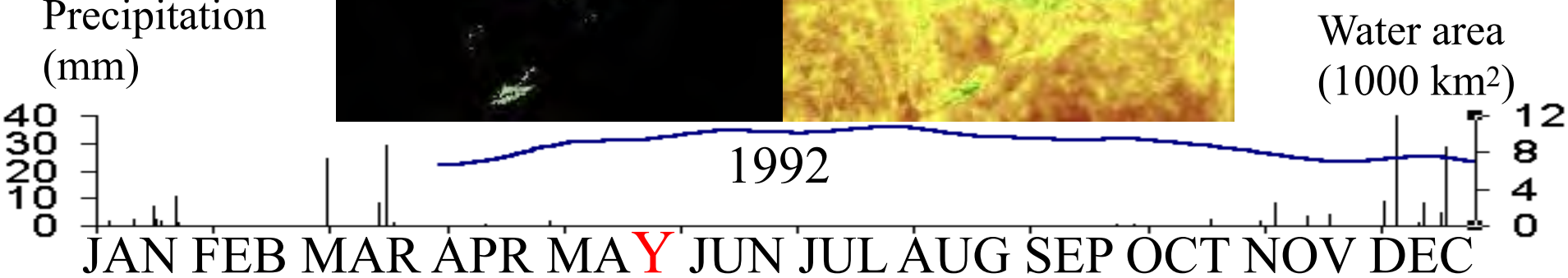




Okavango Delta, Botswana

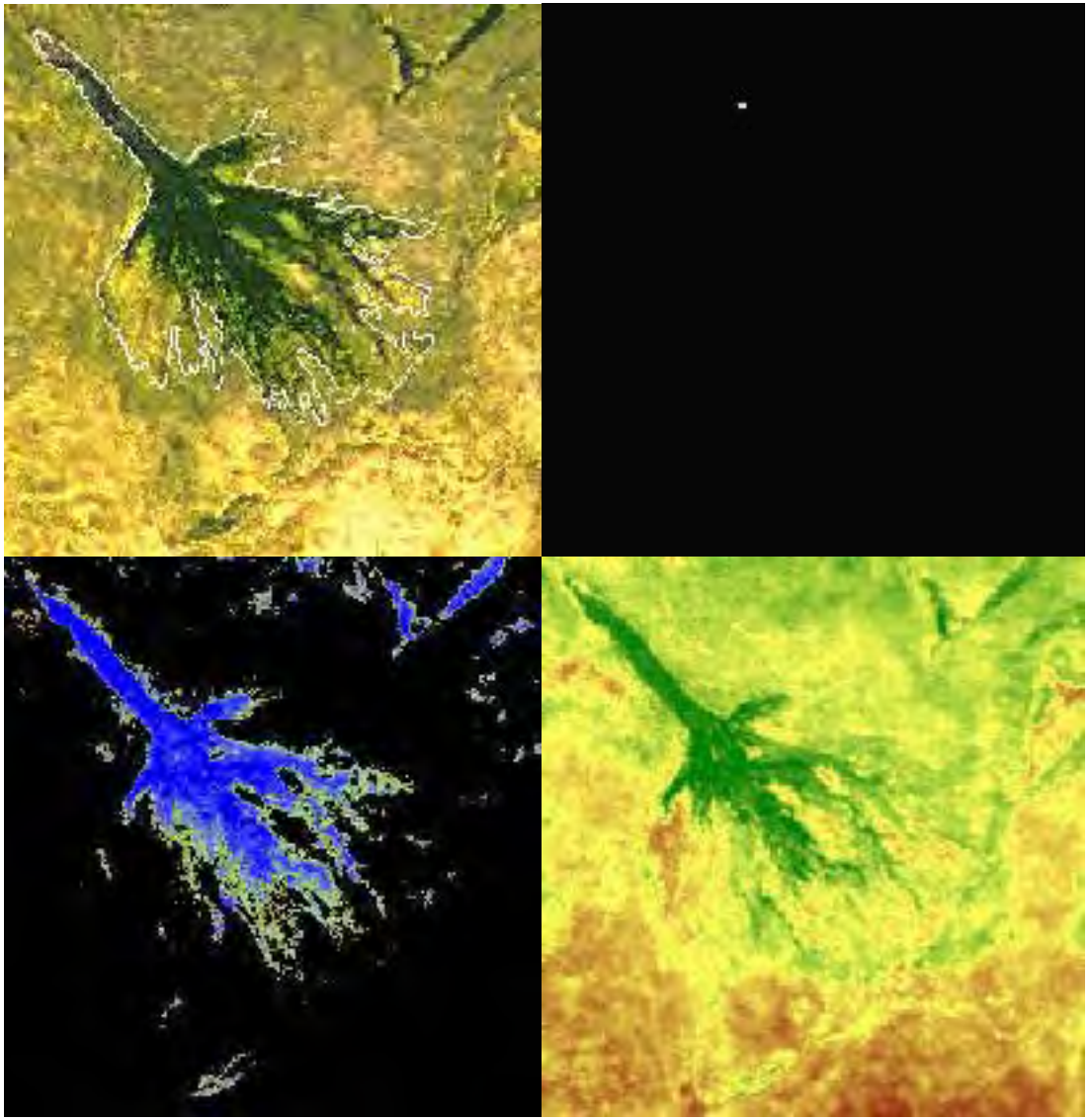
NOAA-AVHRR Images

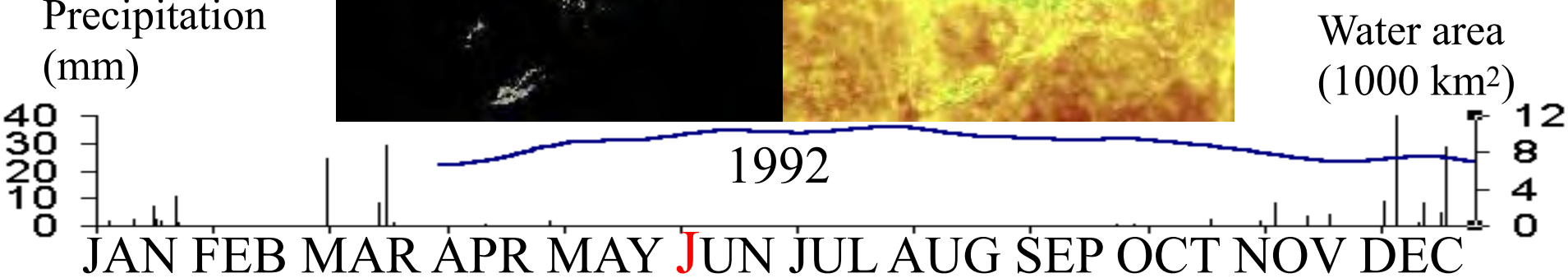




Okavango Delta, Botswana

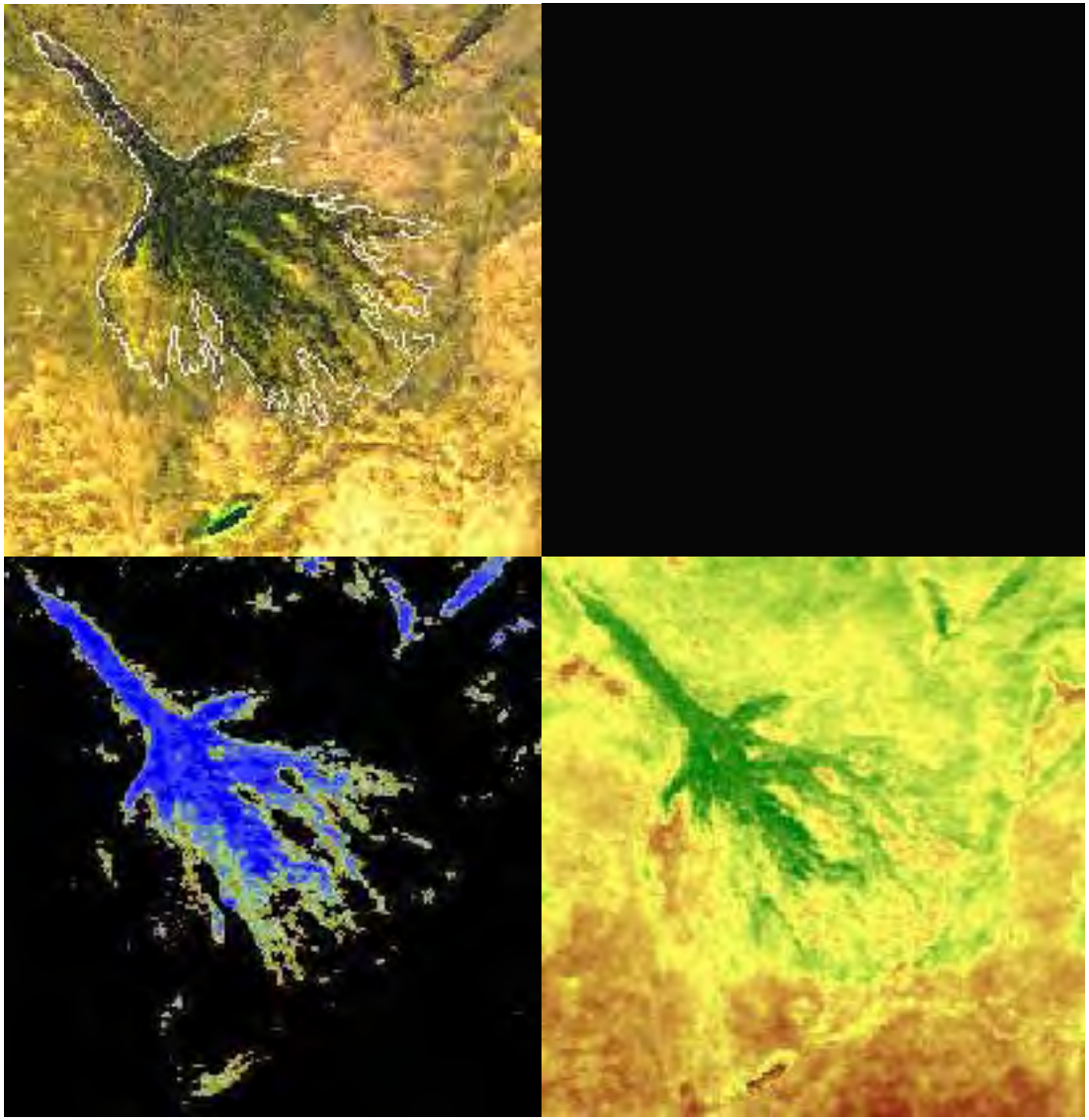
NOAA-AVHRR Images





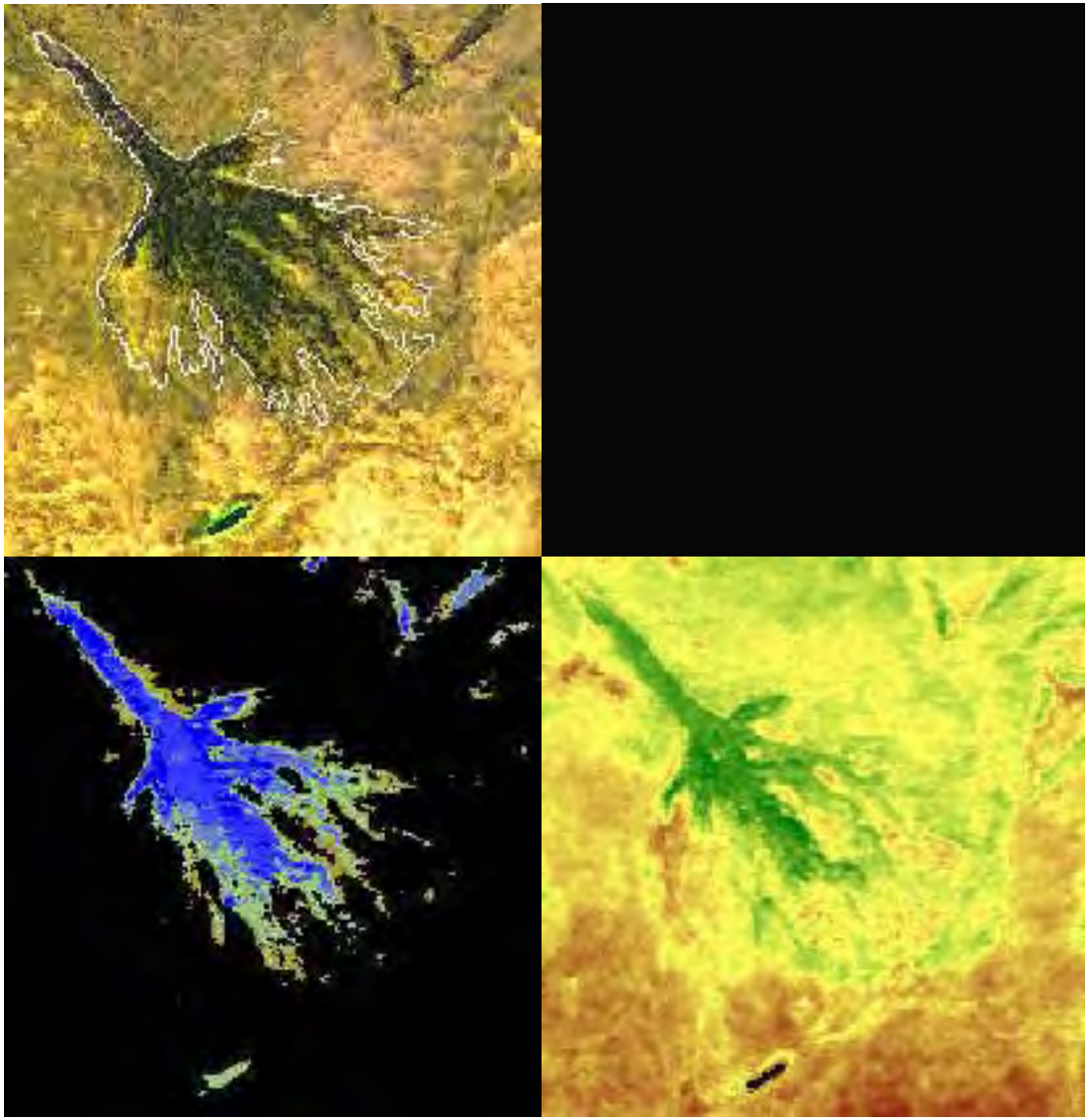
Okavango Delta, Botswana

NOAA-AVHRR Images



Okavango Delta, Botswana

NOAA-AVHRR Images



Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

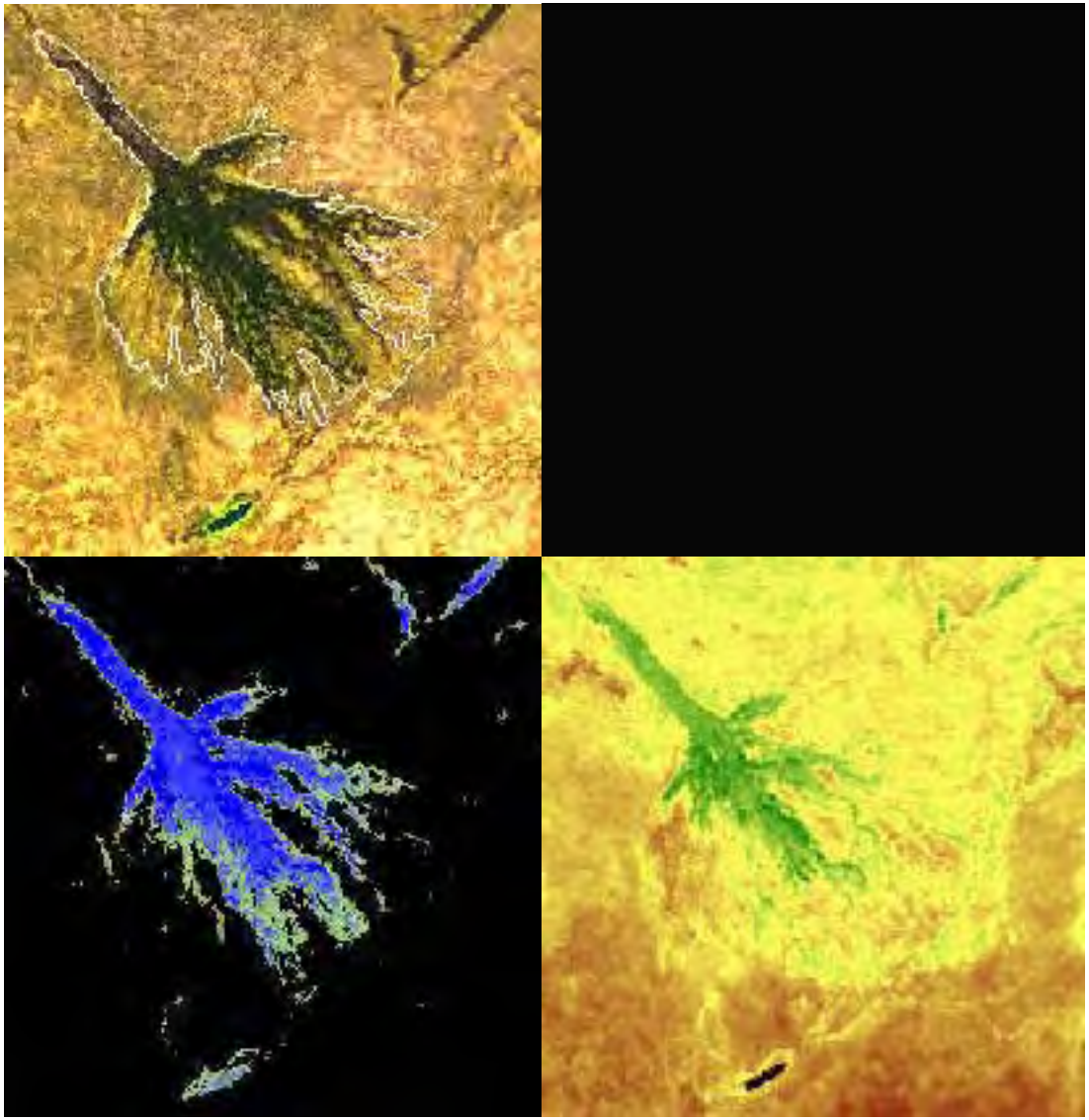
100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images



True colours

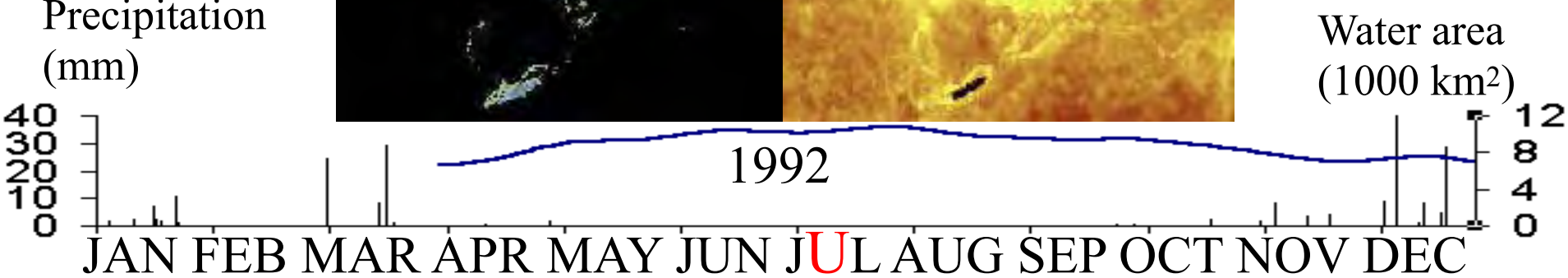
Clouds

Water

NDVI

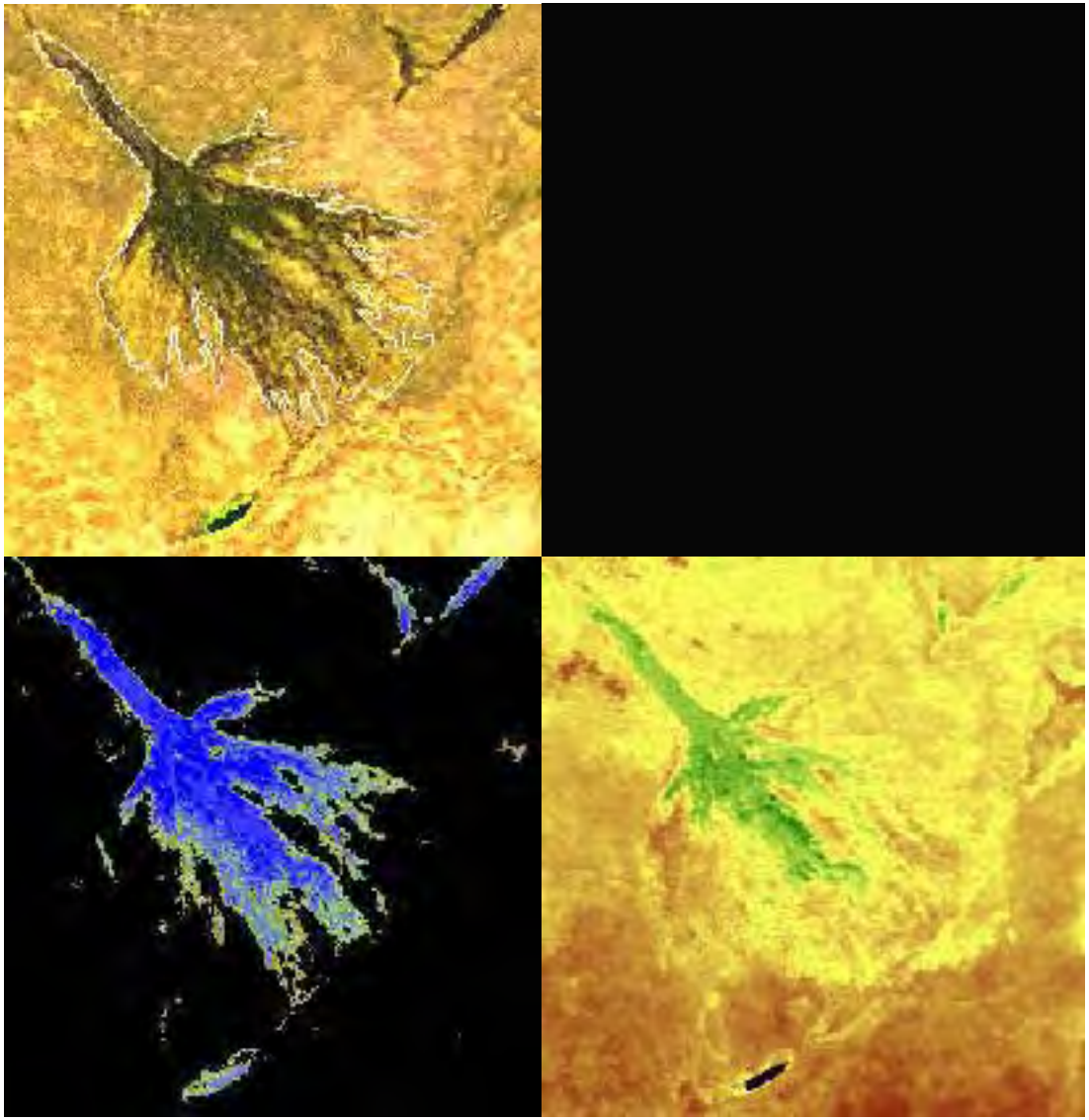
N

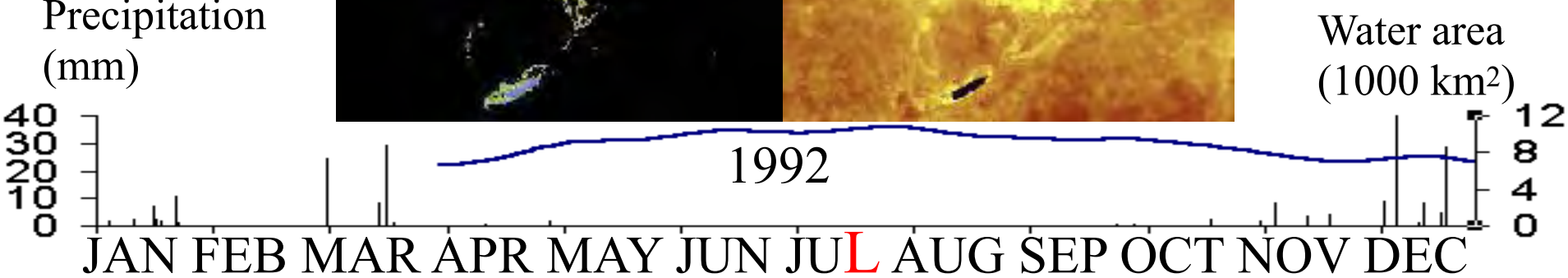
100 Km



Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

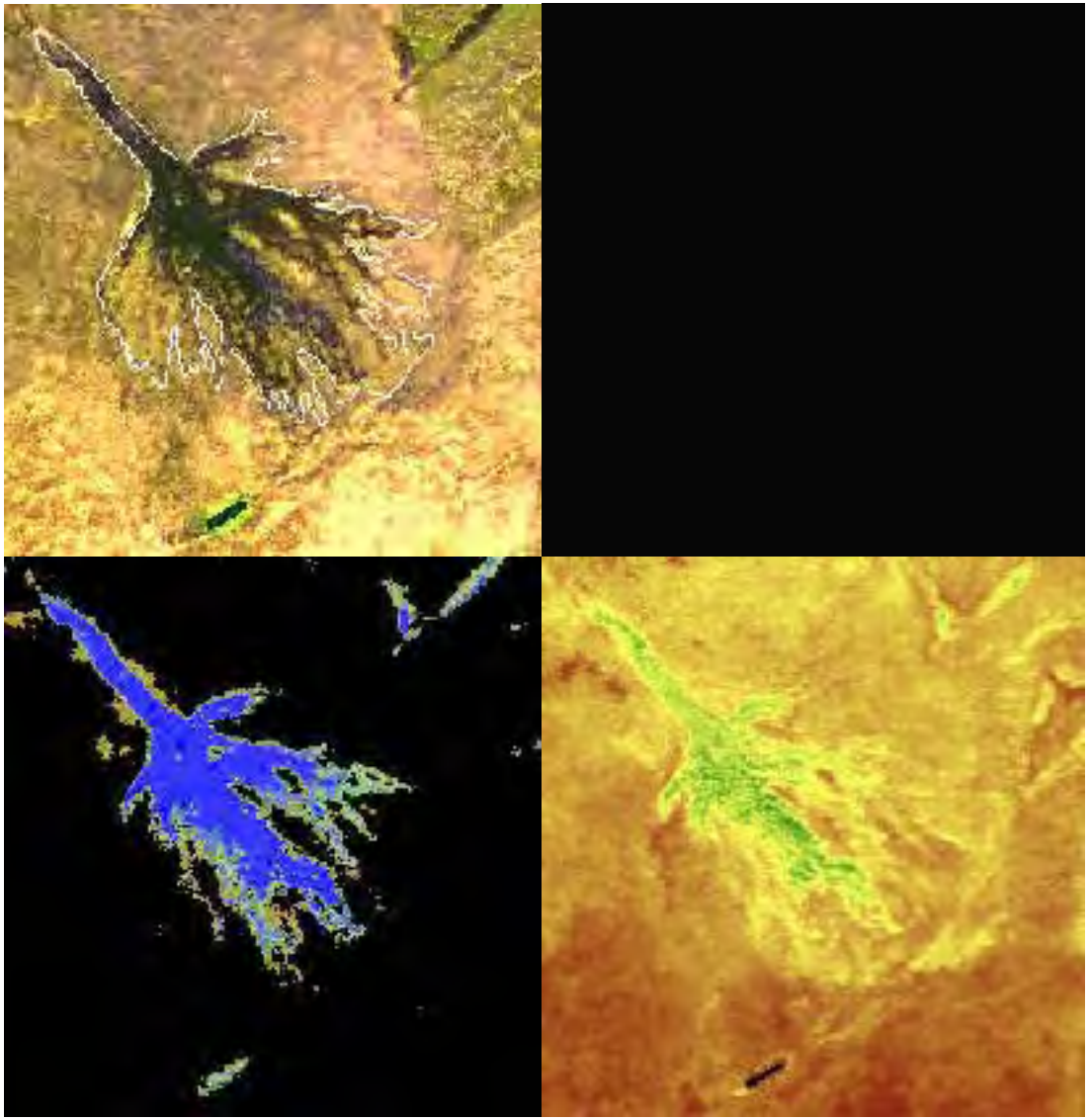
100 Km

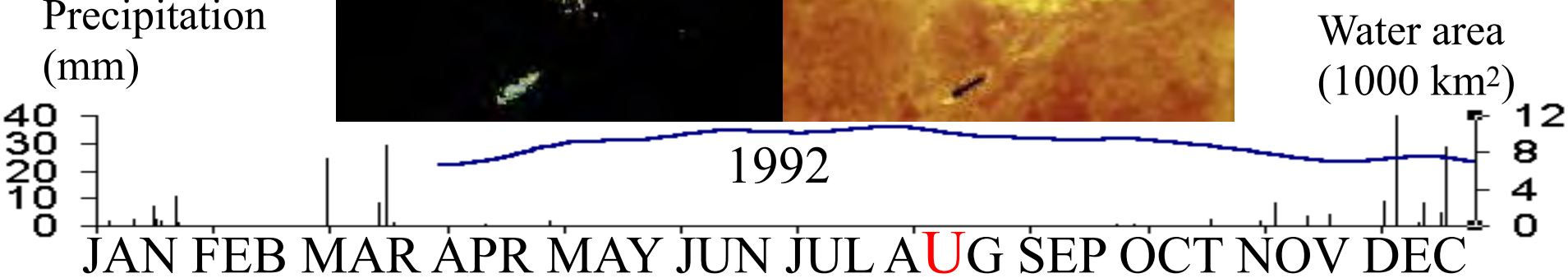
Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

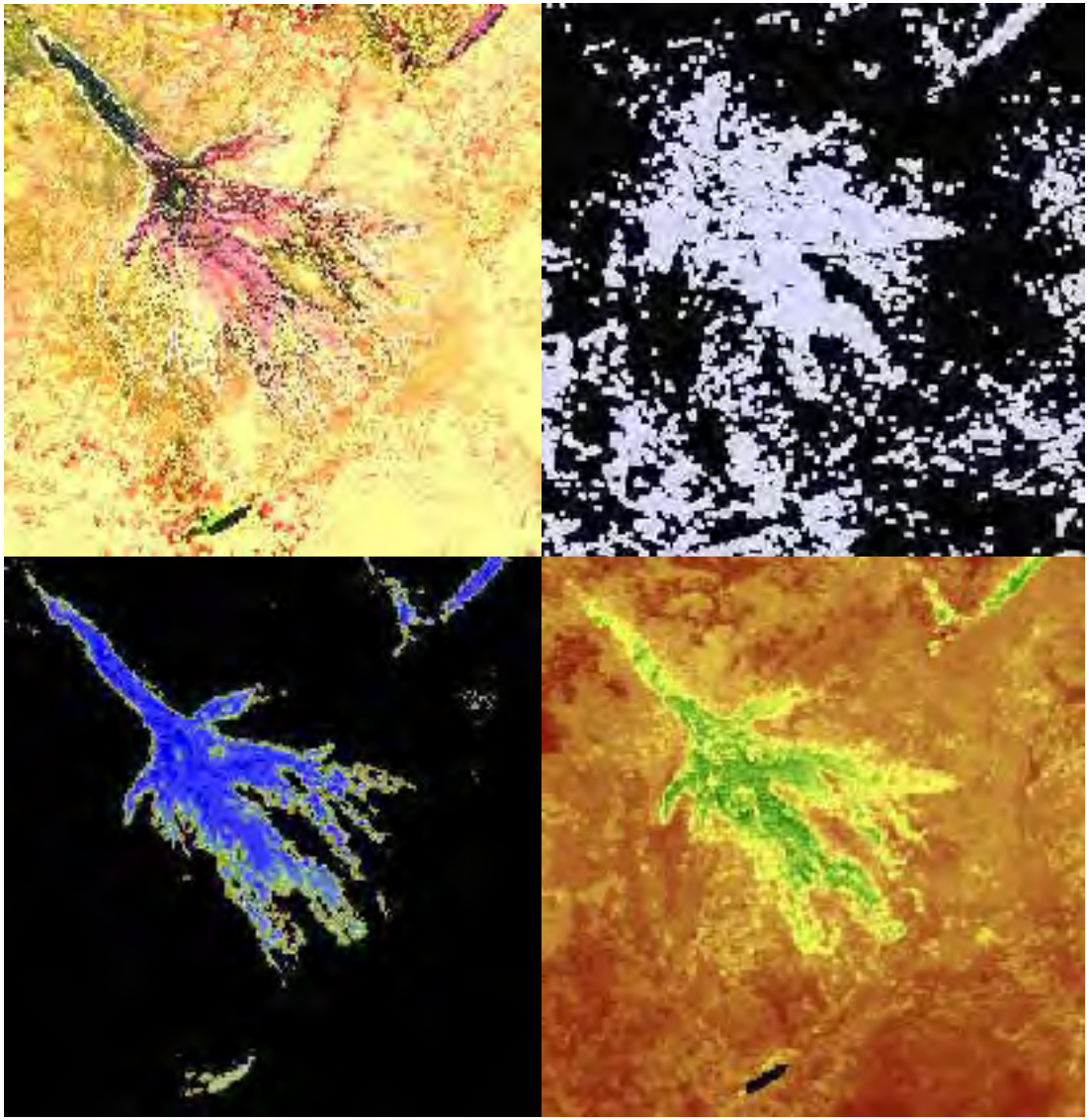
100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images



True colours

Clouds

Water

NDVI

N

100 Km

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

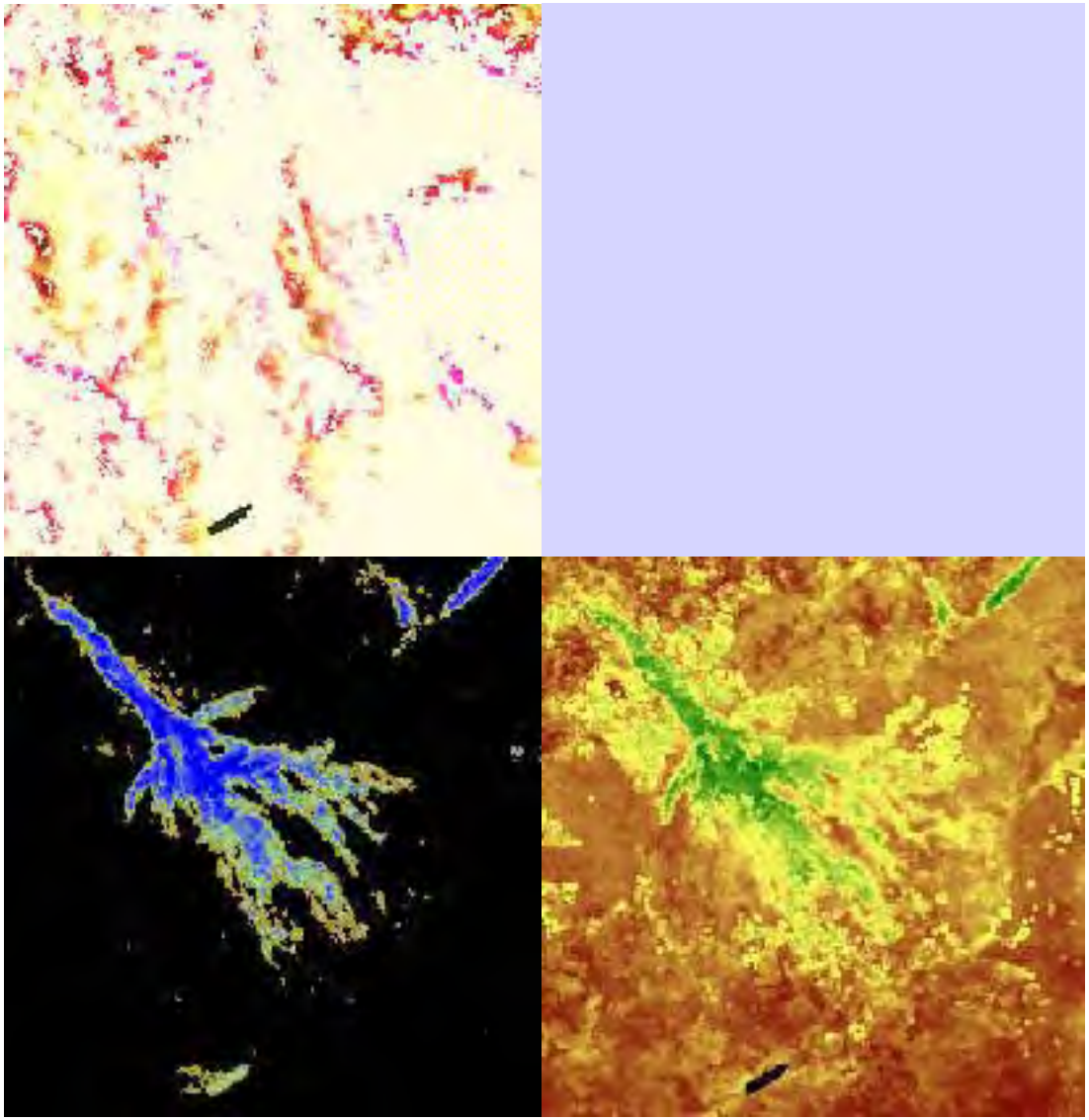
NDVI

N

100 Km

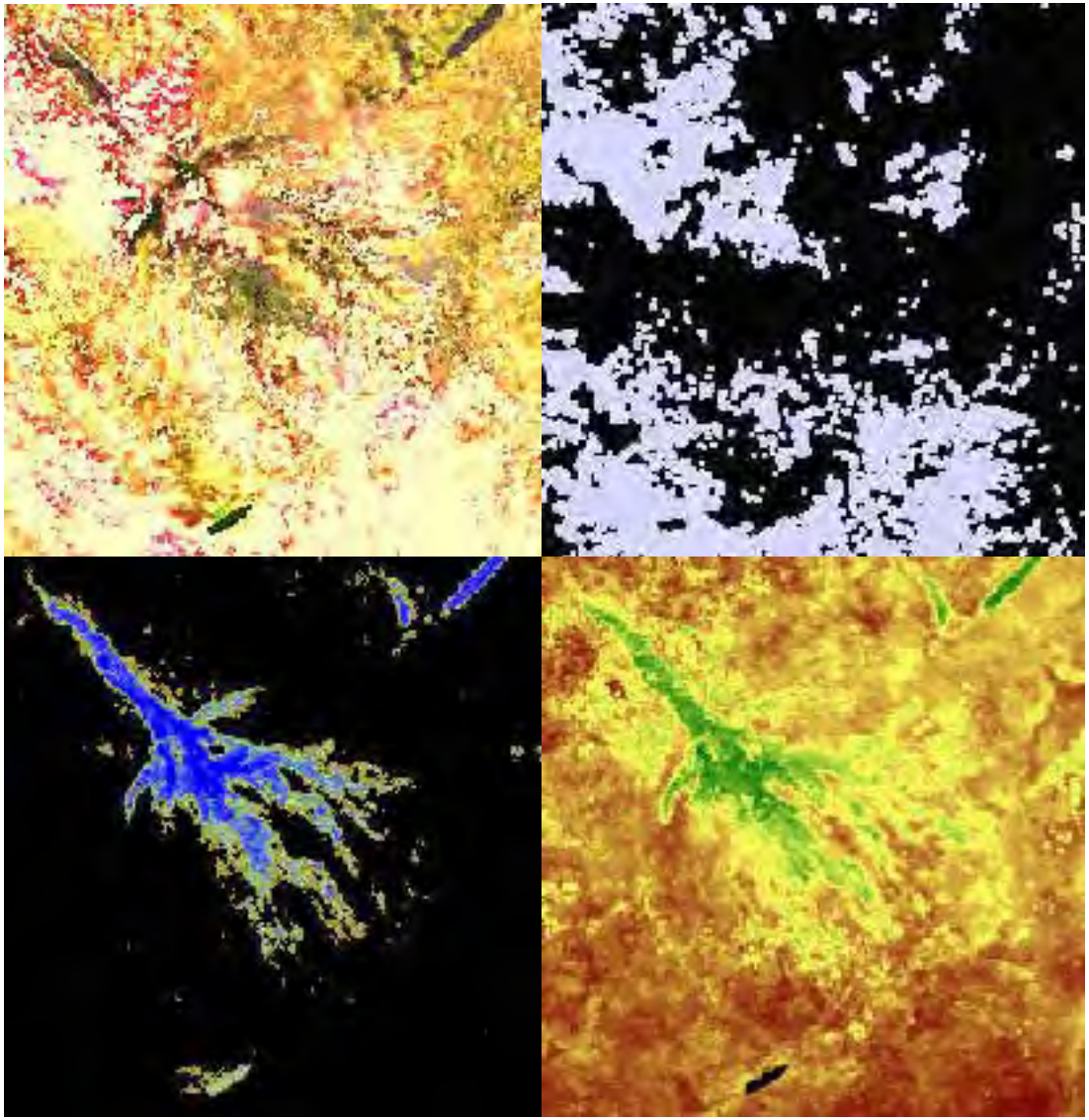
Okavango Delta, Botswana

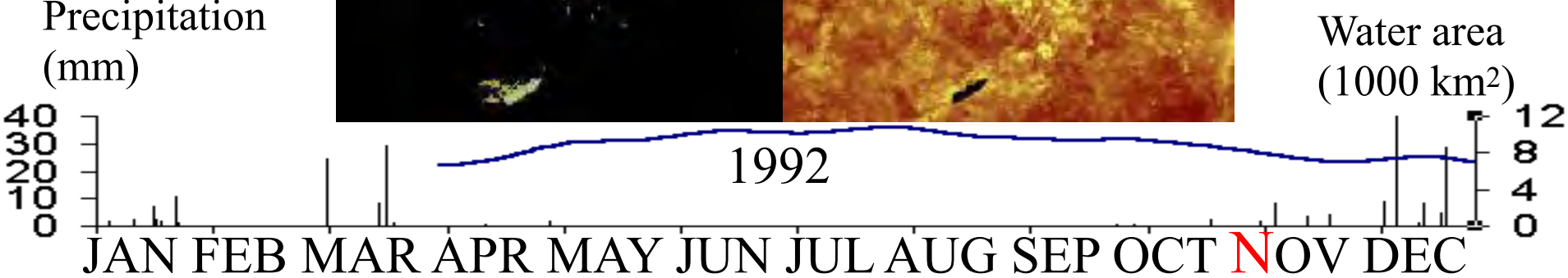
NOAA-AVHRR Images



Okavango Delta, Botswana

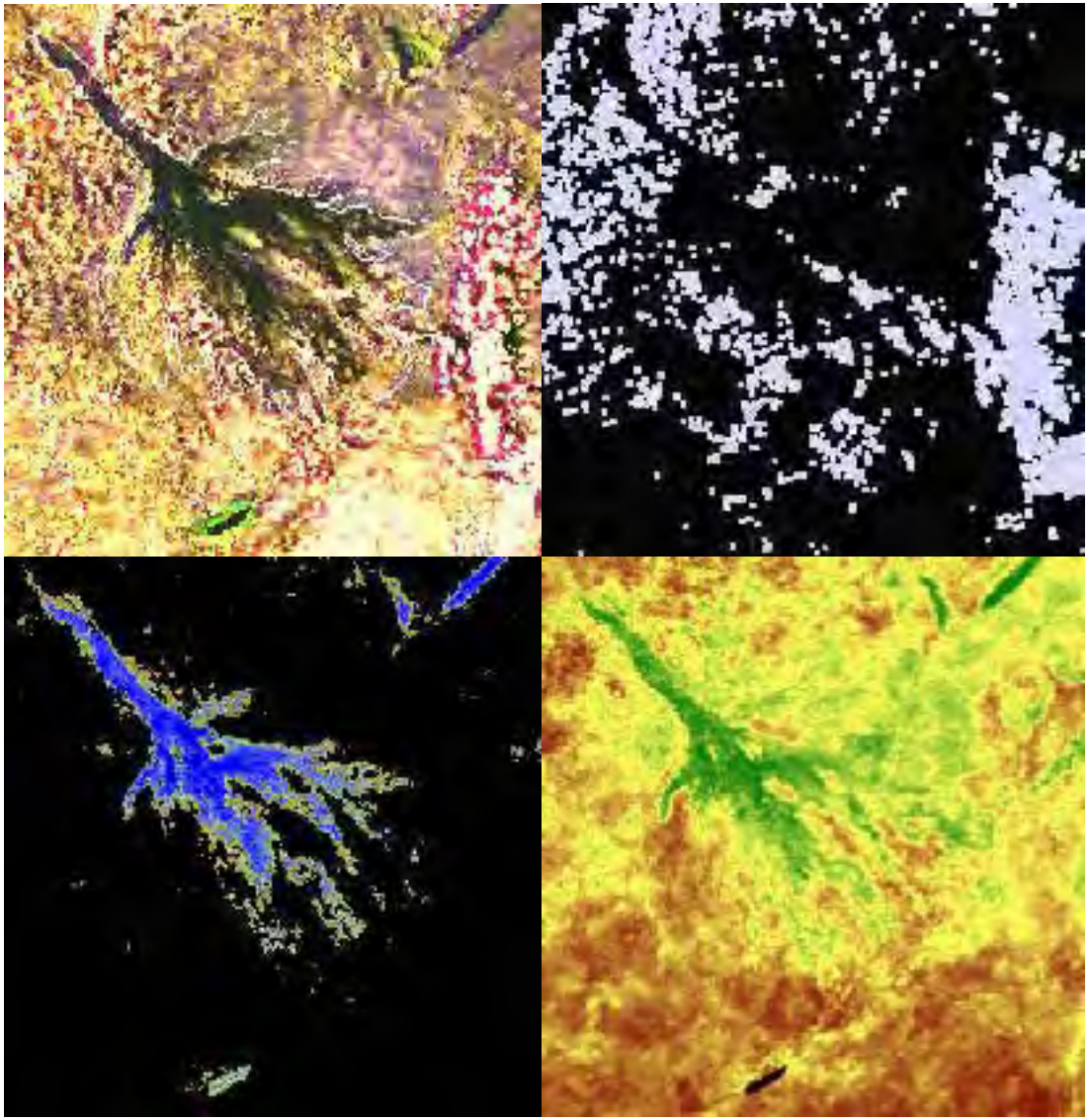
NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images



True colours

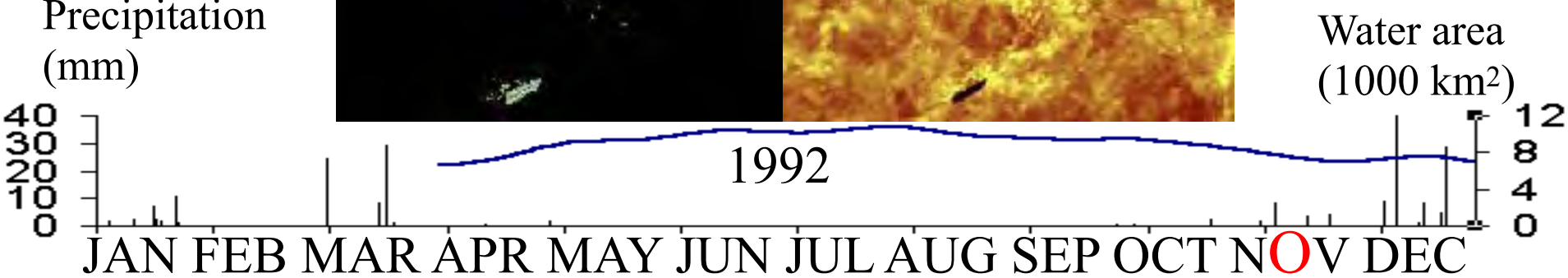
Clouds

Water

NDVI

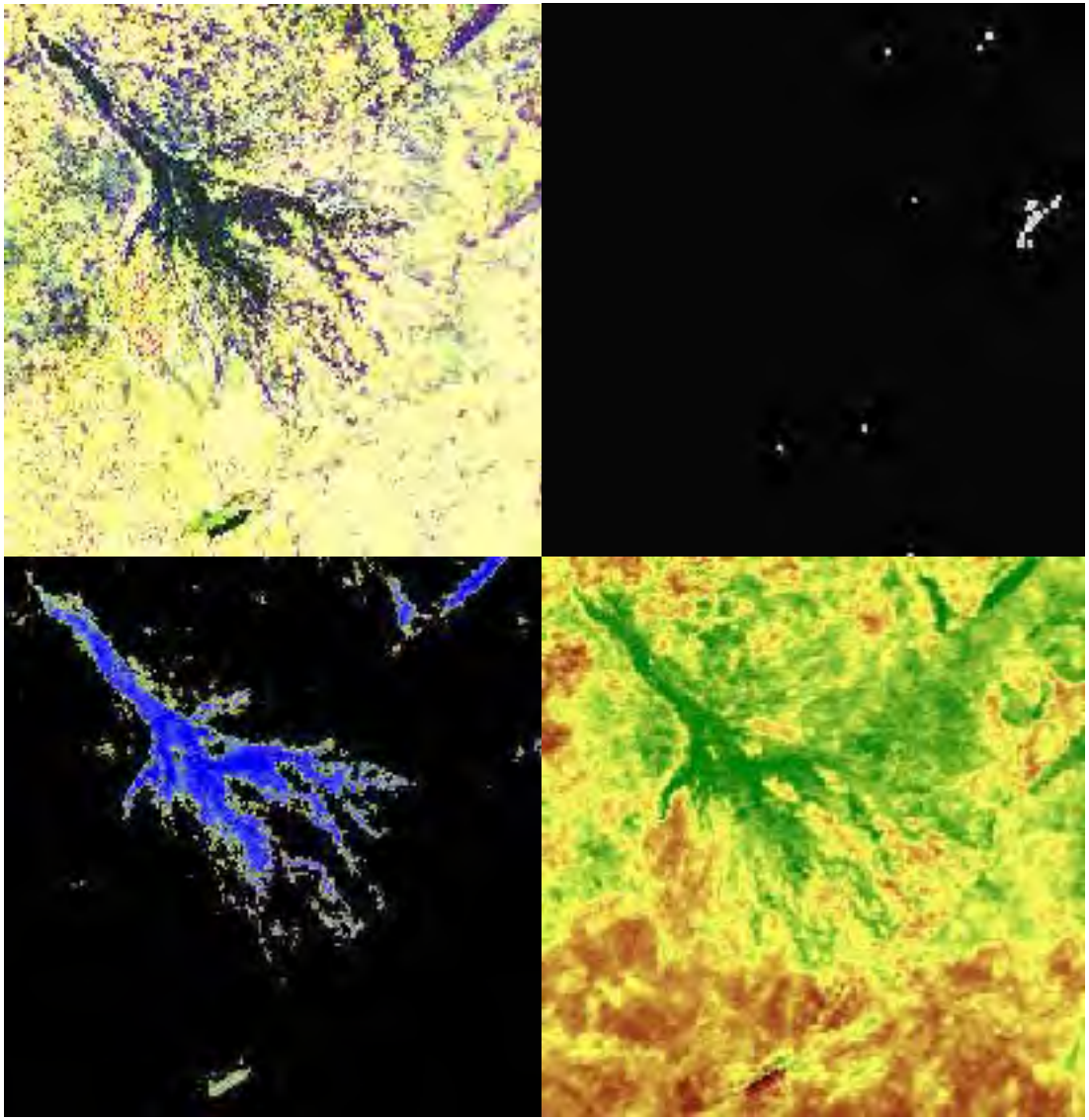
N

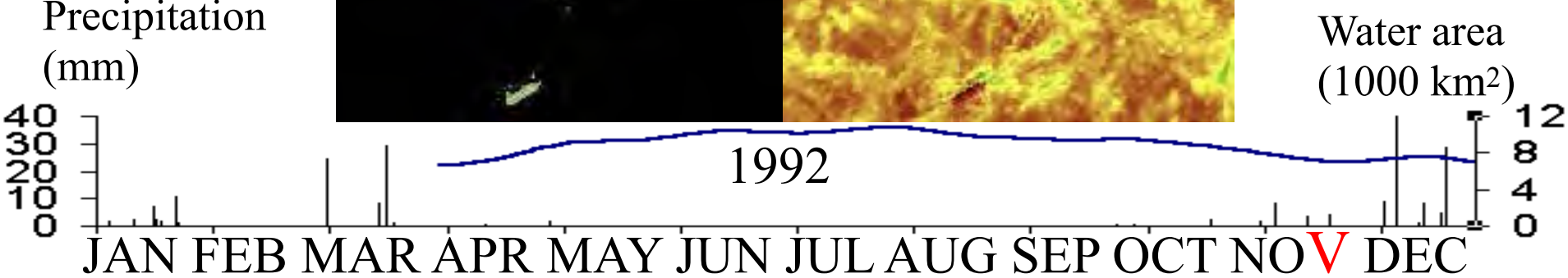
100 Km



Okavango Delta, Botswana

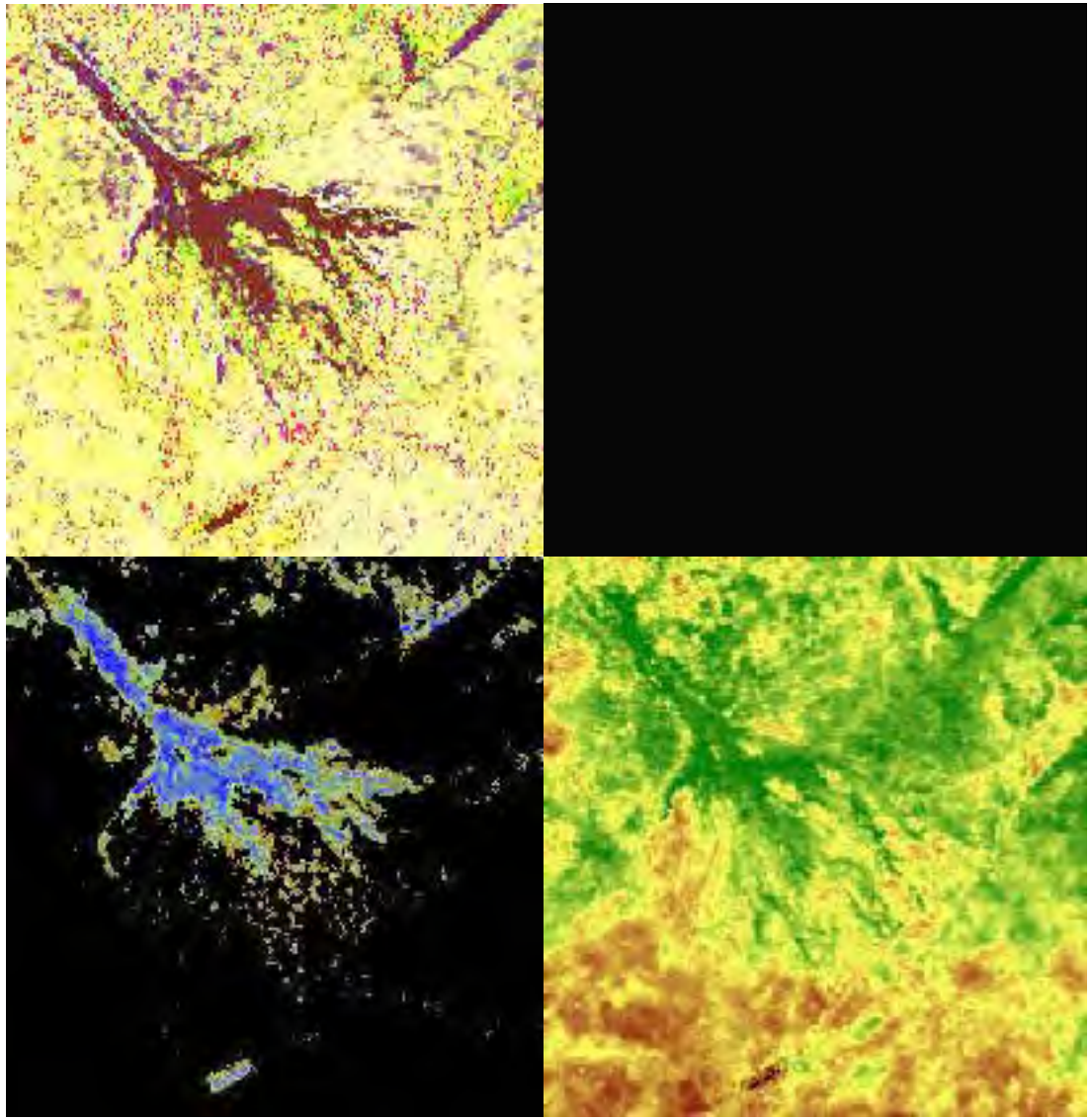
NOAA-AVHRR Images

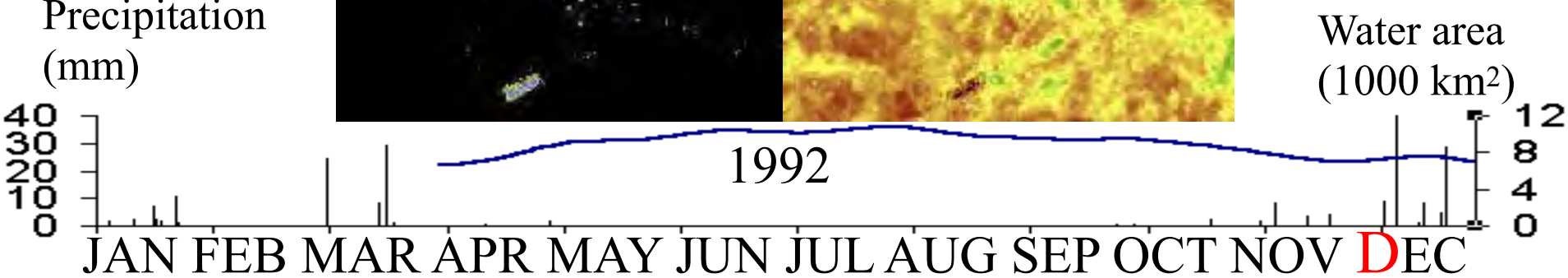




Okavango Delta, Botswana

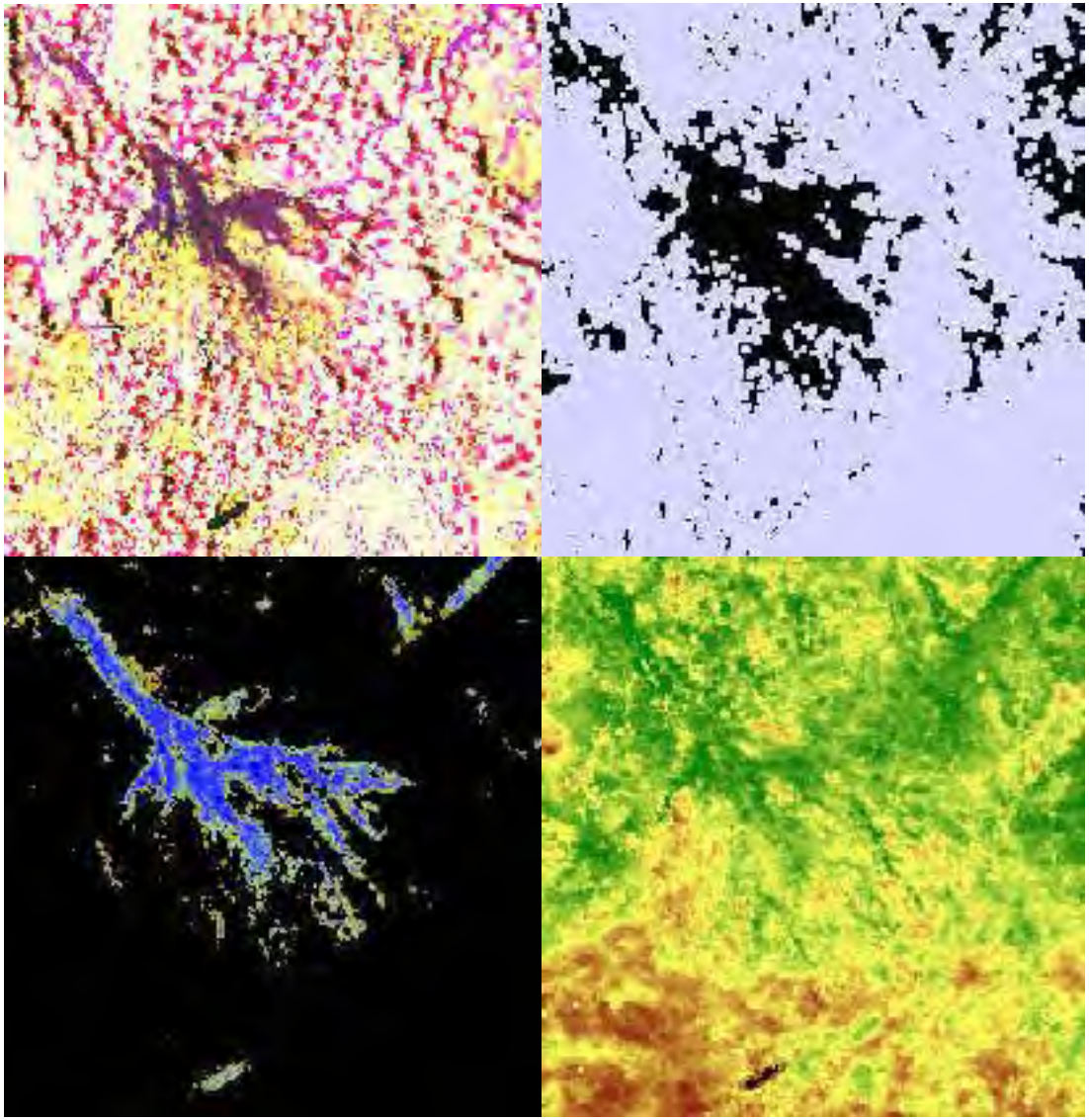
NOAA-AVHRR Images

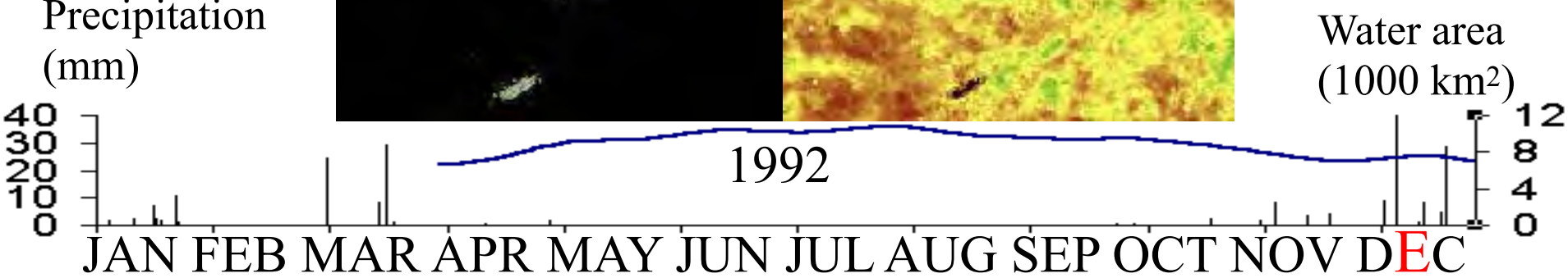




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

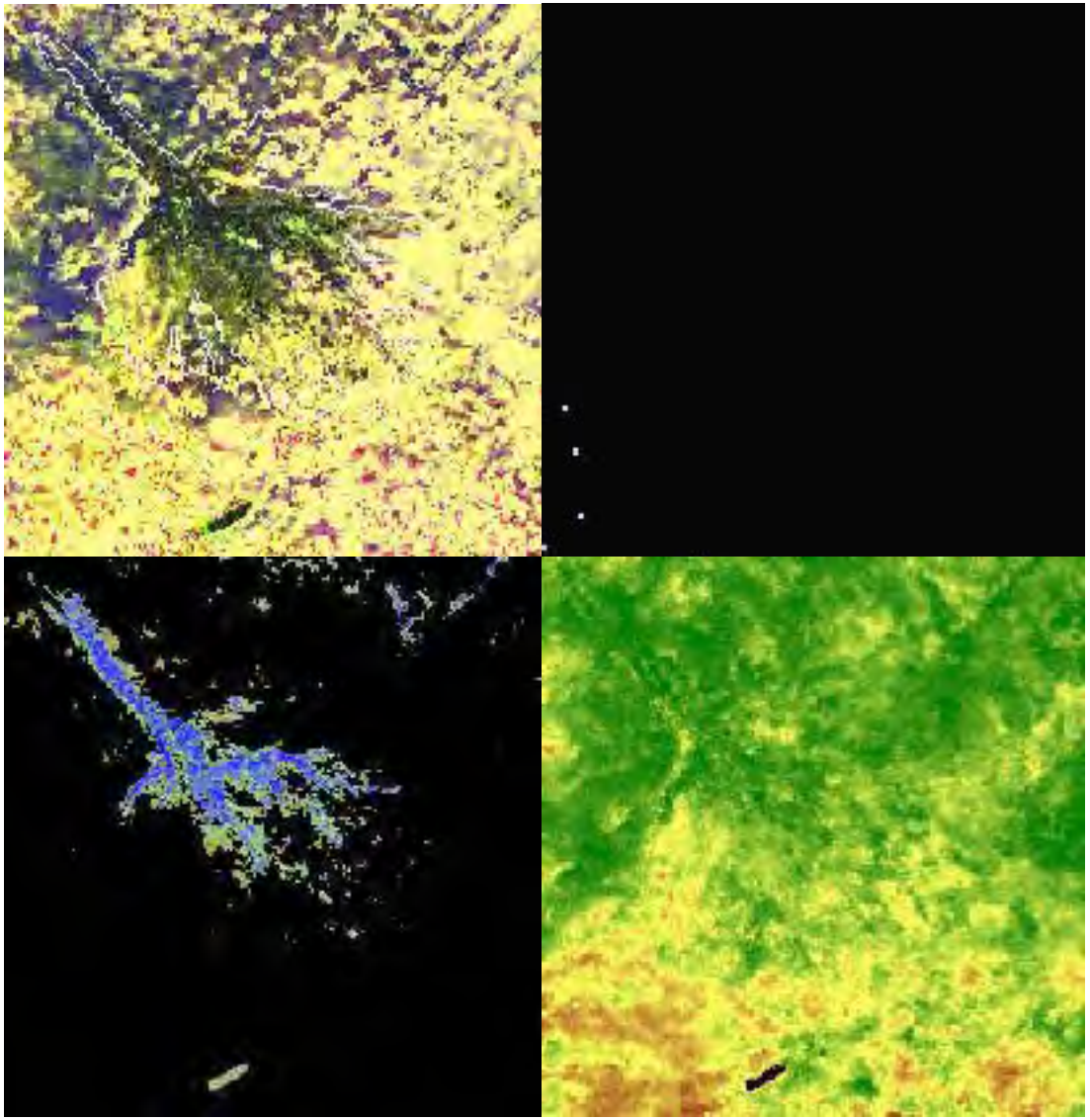
100 Km

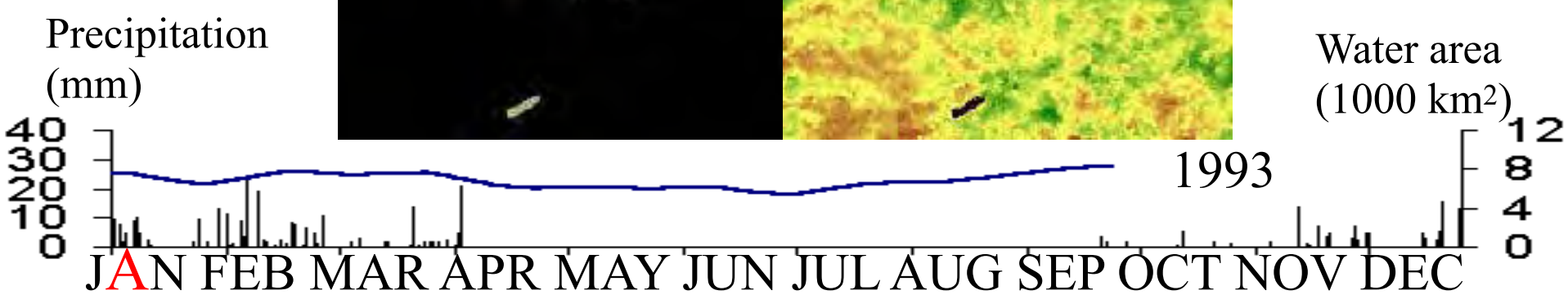
Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

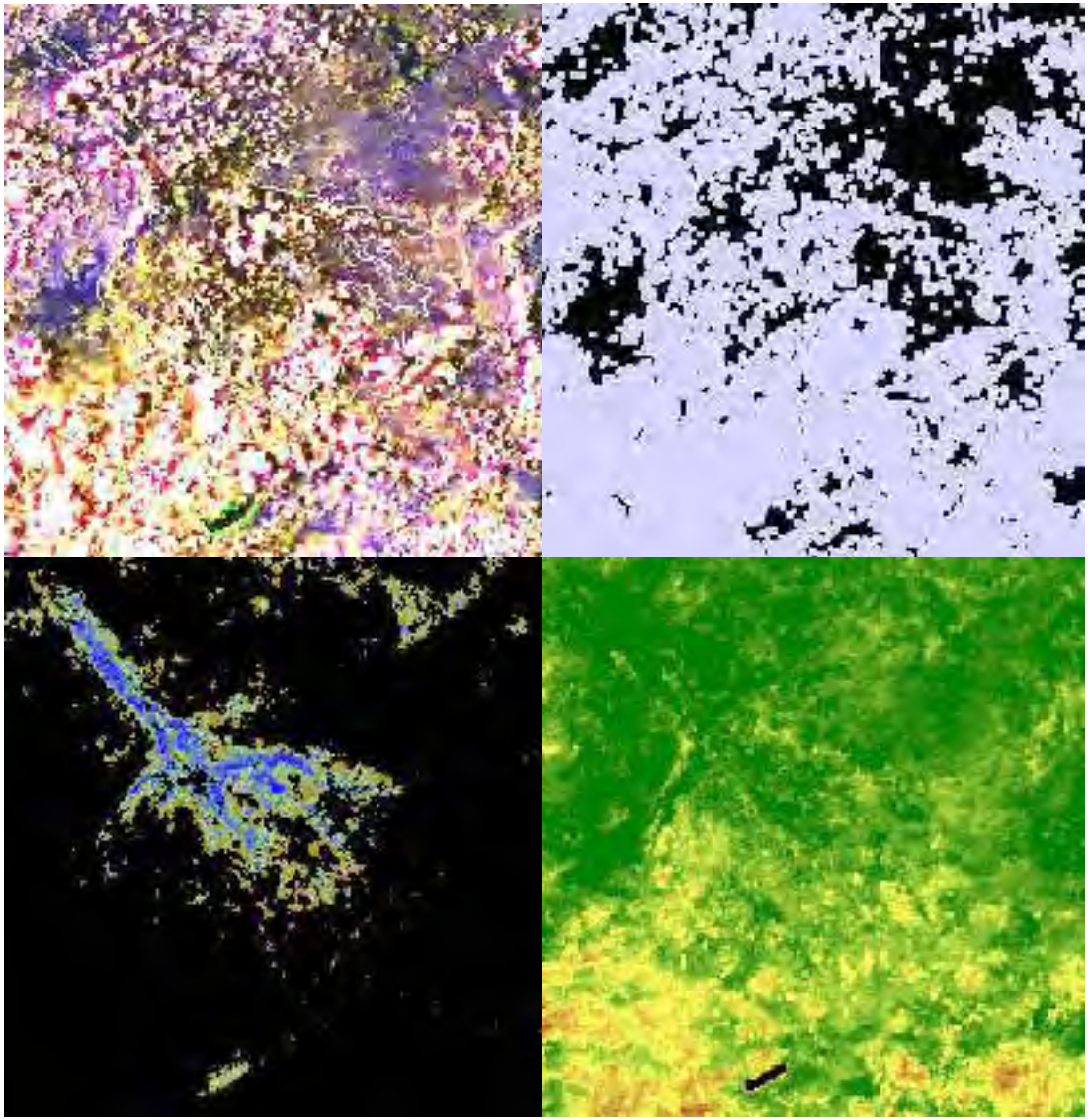
NOAA-AVHRR Images

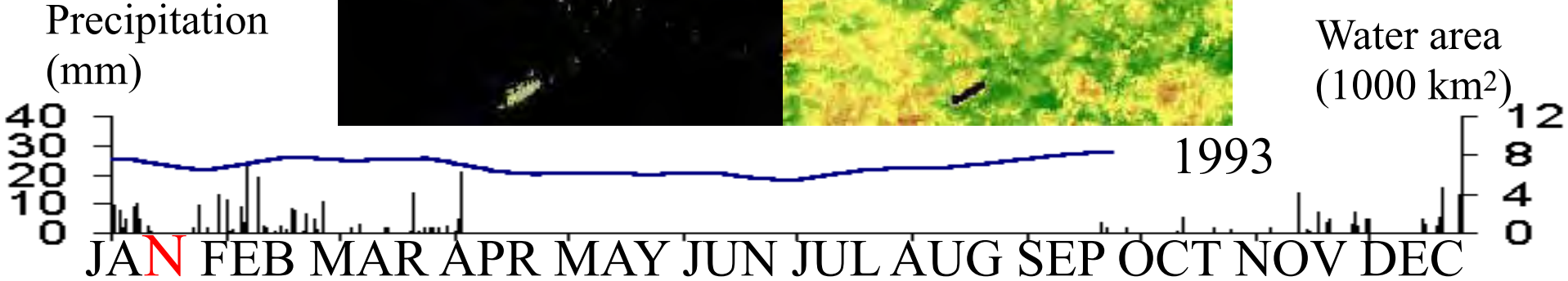




Okavango Delta, Botswana

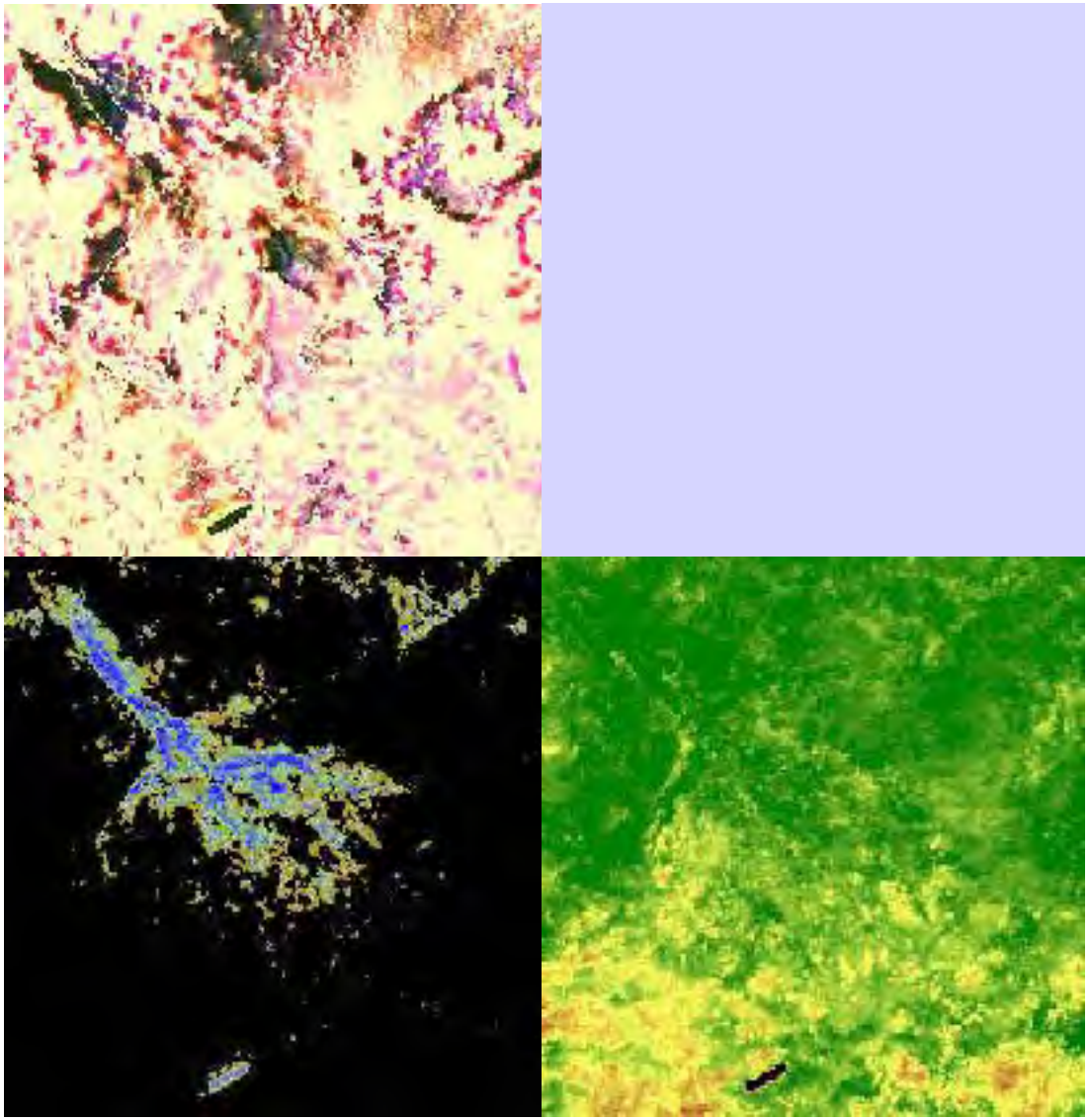
NOAA-AVHRR Images

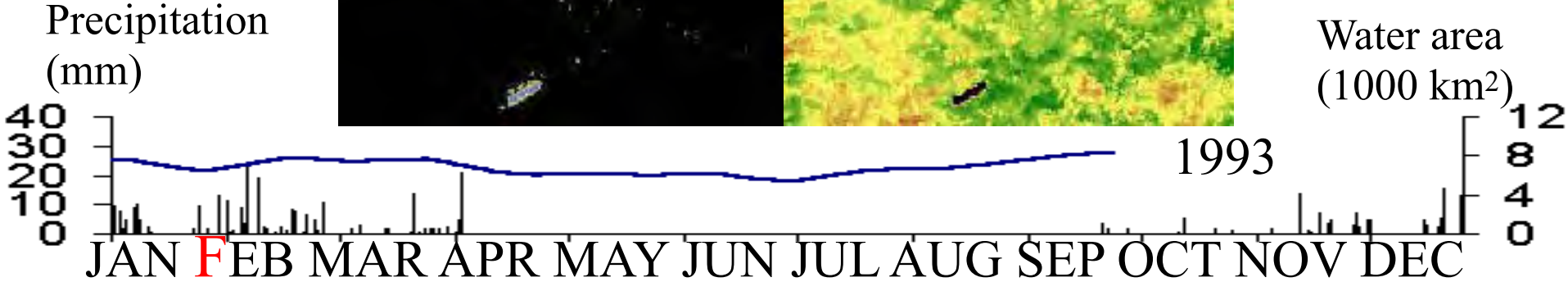




Okavango Delta, Botswana

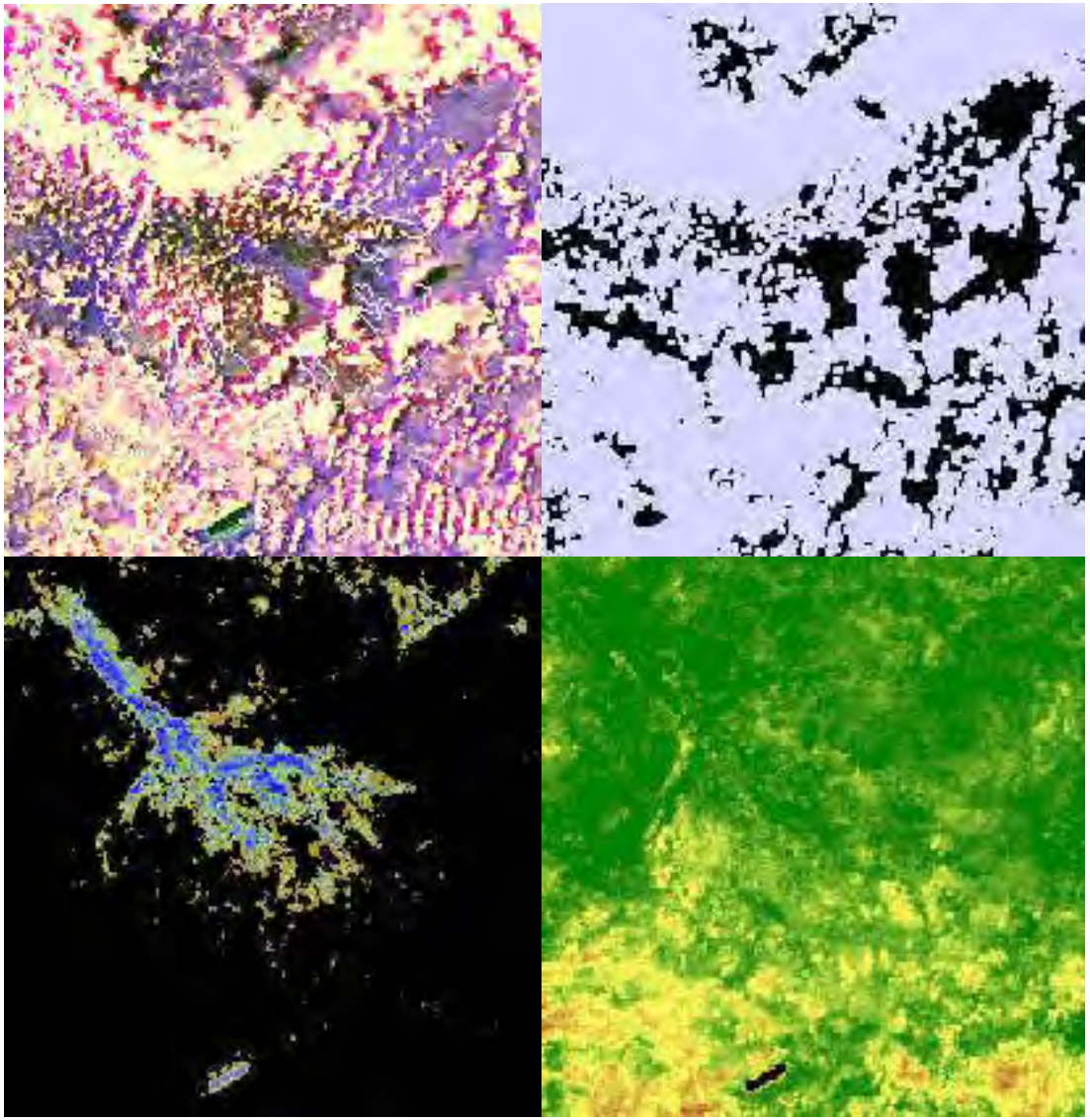
NOAA-AVHRR Images

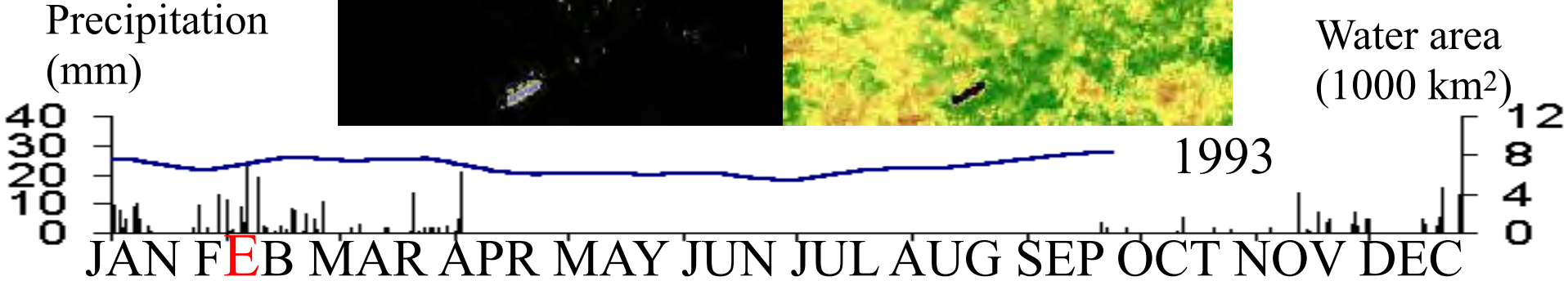




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

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NDVI

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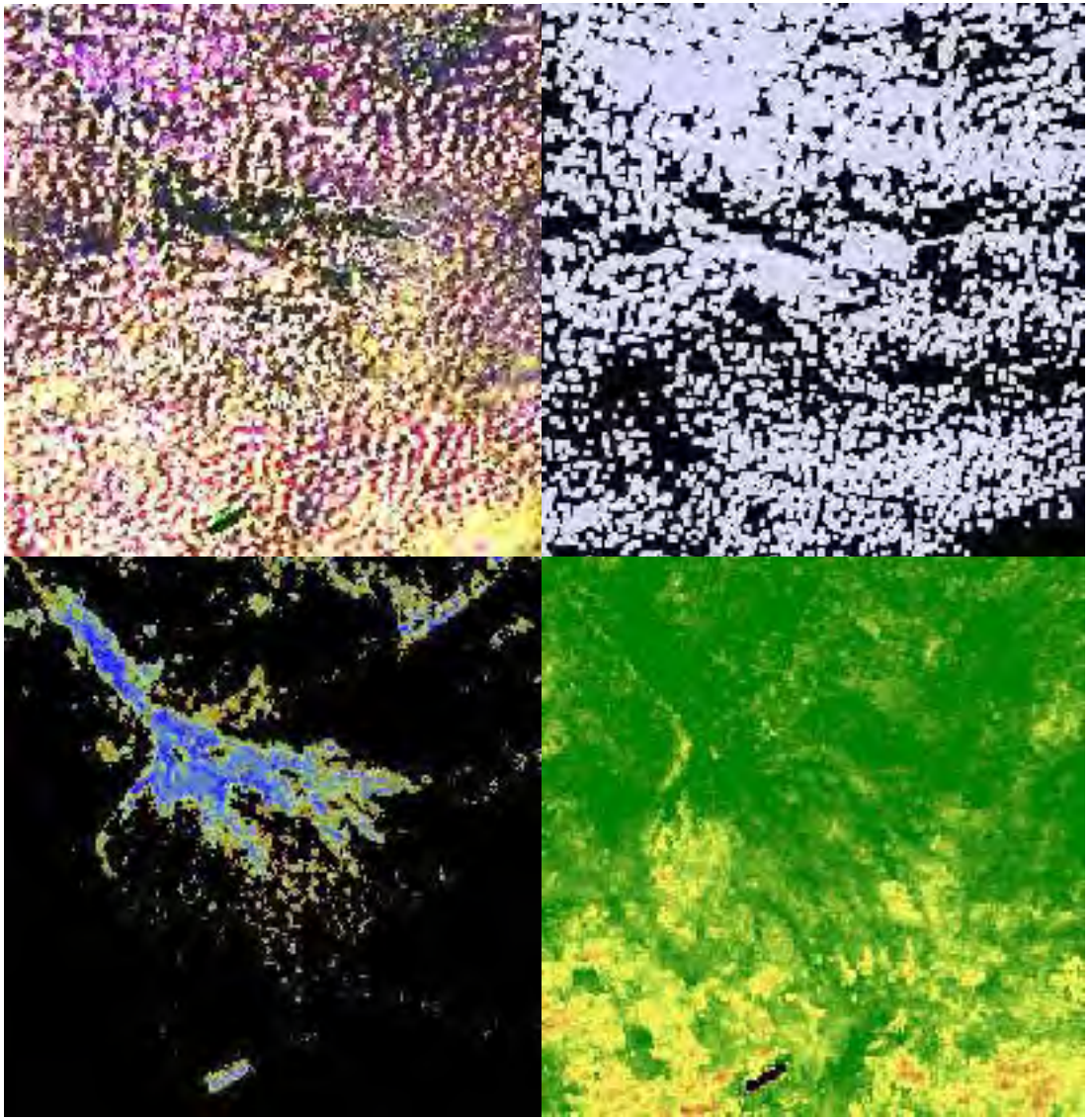
100 Km

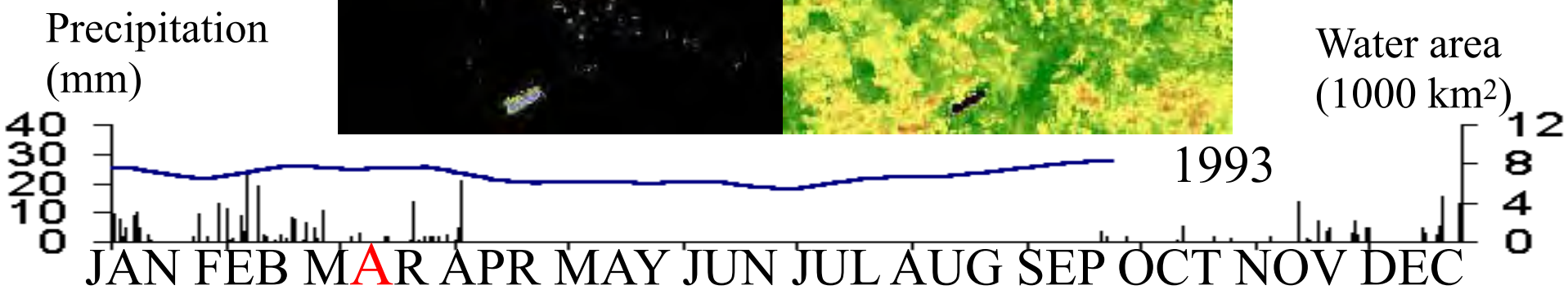
Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

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100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

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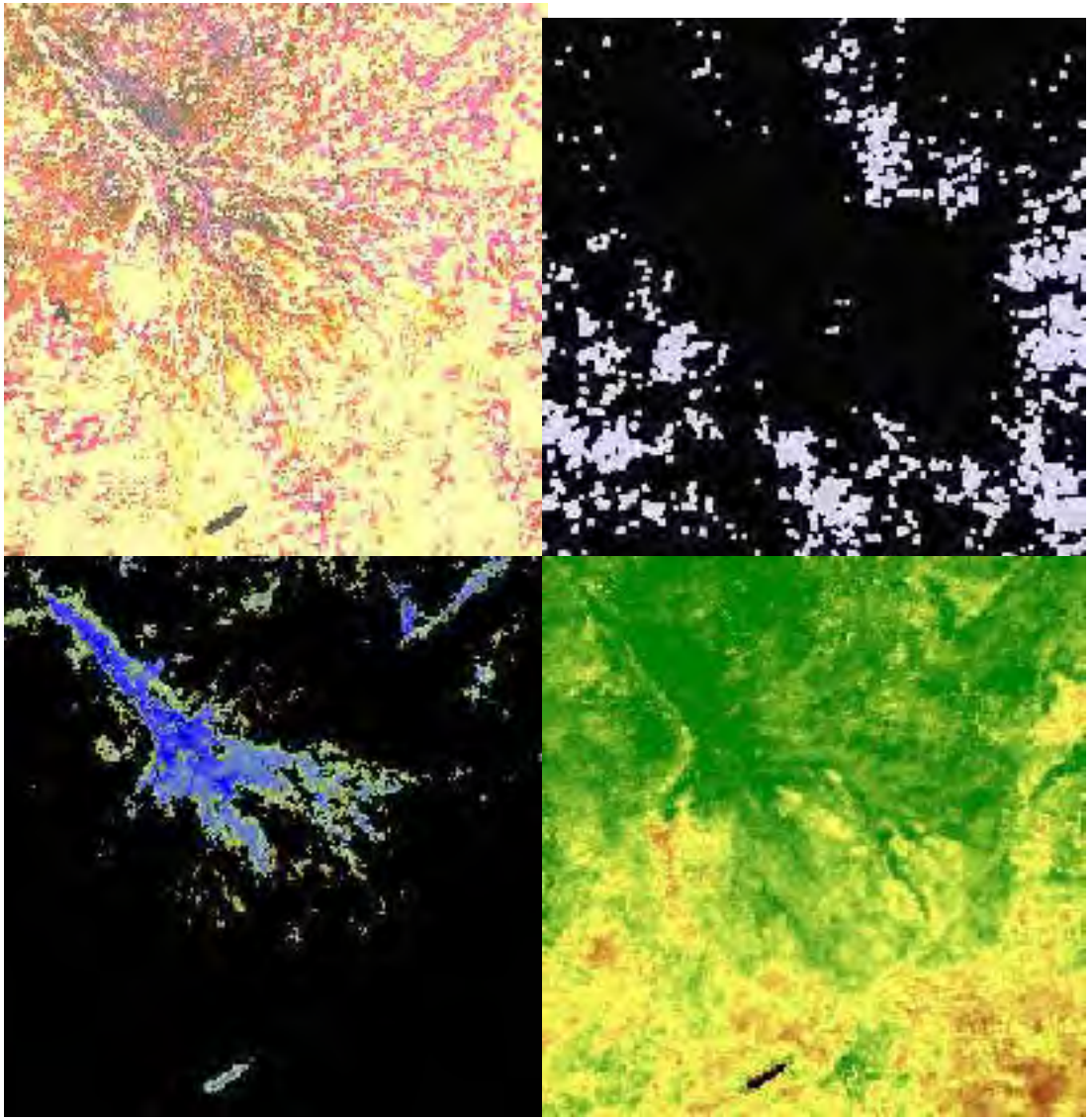
Okavango Delta, Botswana

NOAA-AVHRR Images



True colours

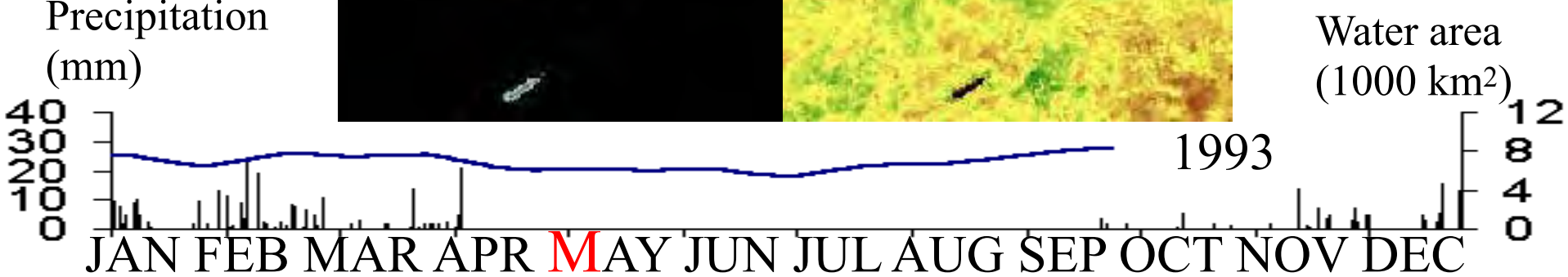
Clouds

Water

NDVI

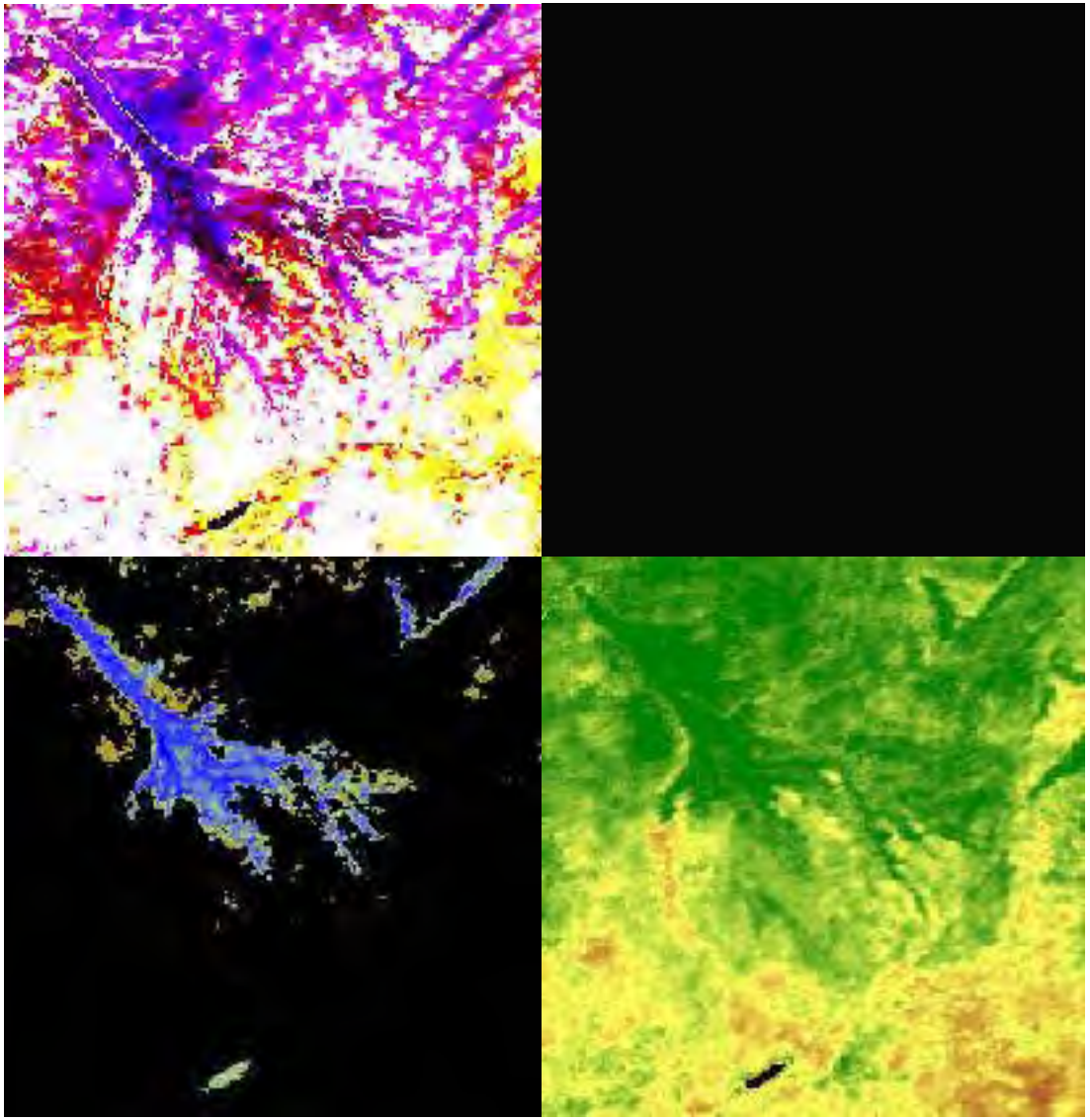
N

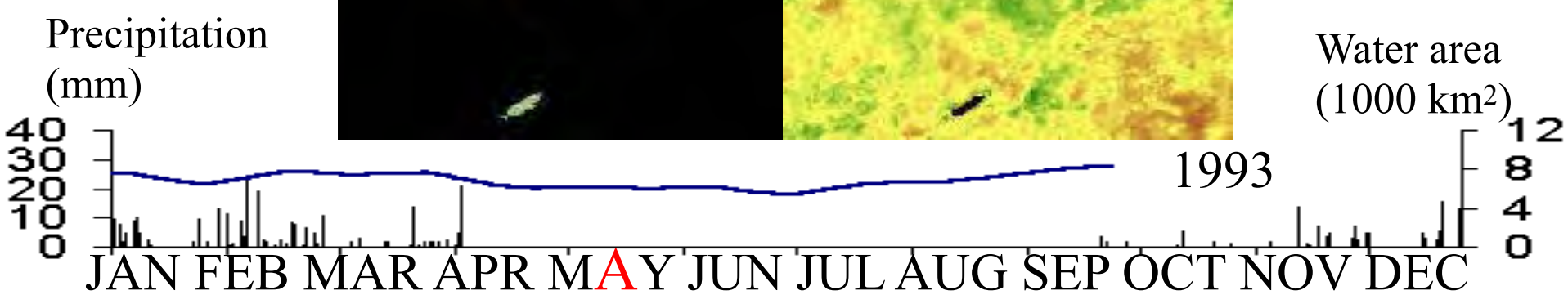
100 Km



Okavango Delta, Botswana

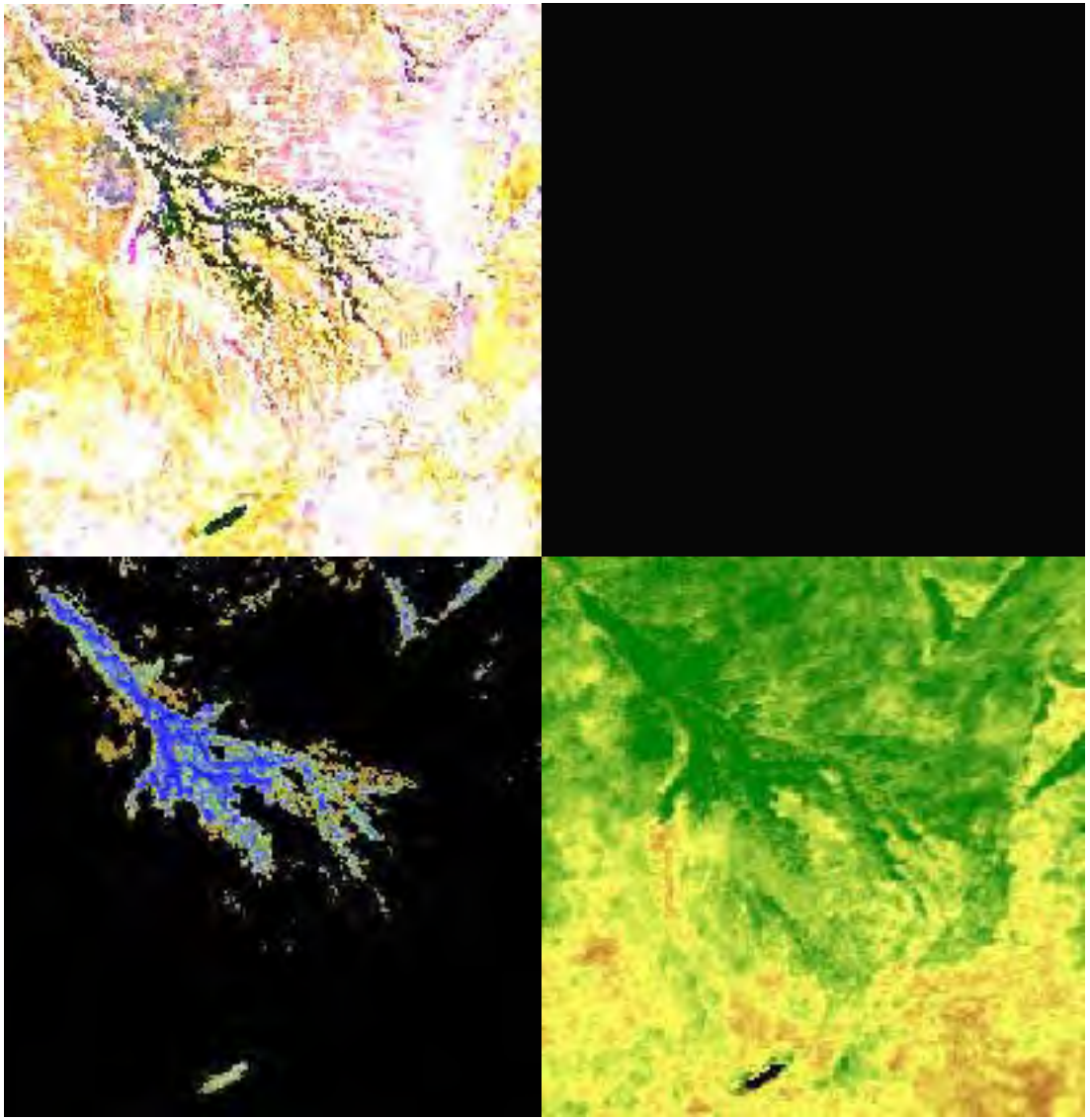
NOAA-AVHRR Images

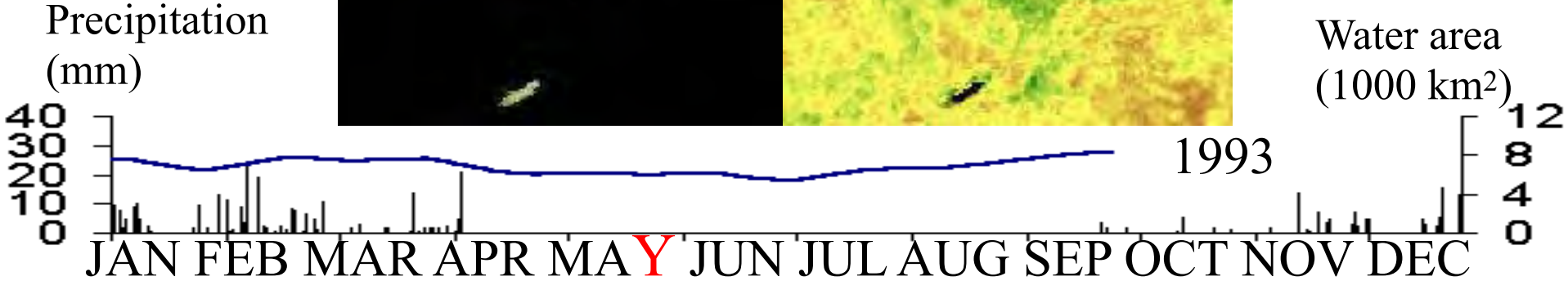




Okavango Delta, Botswana

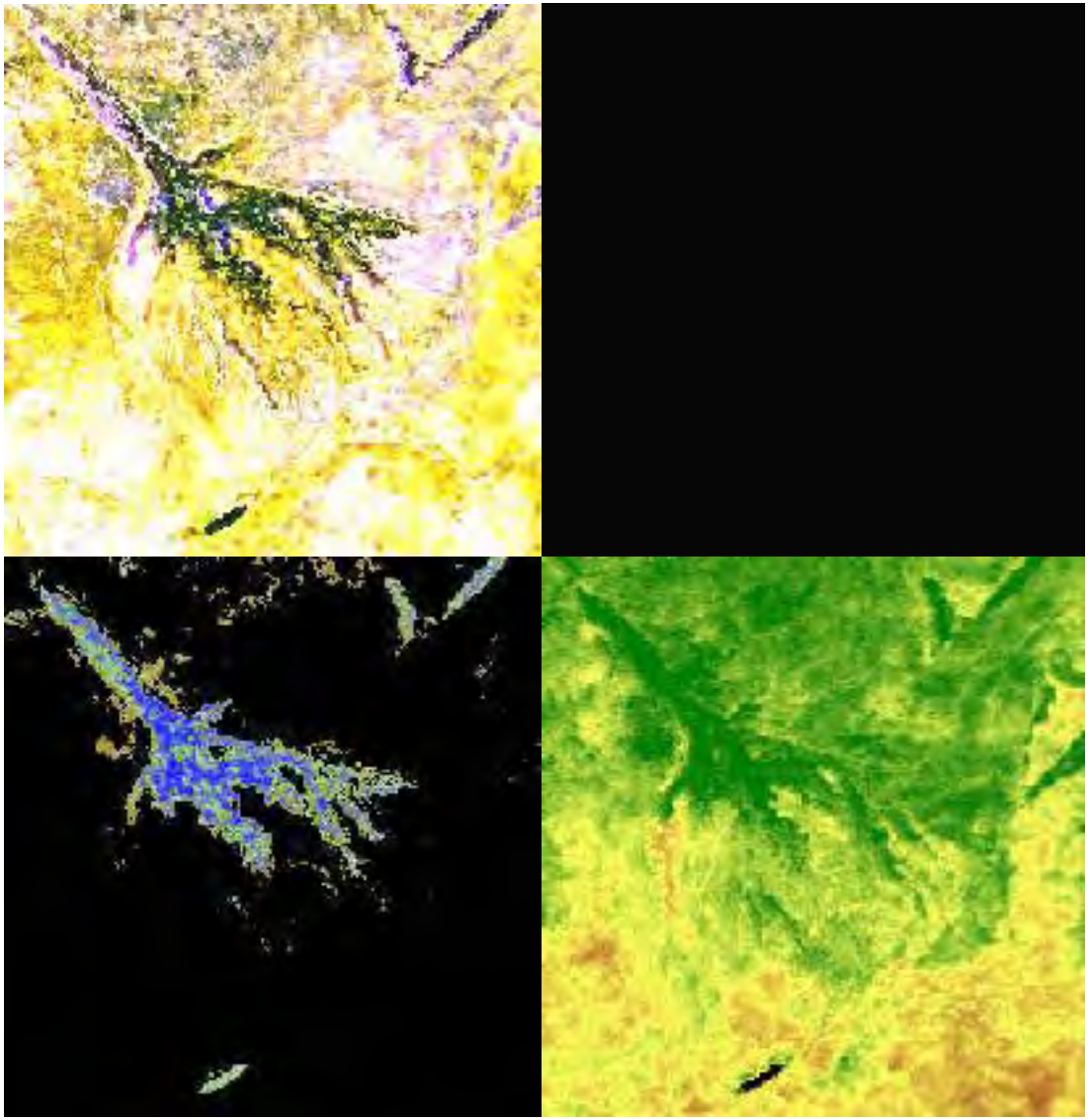
NOAA-AVHRR Images

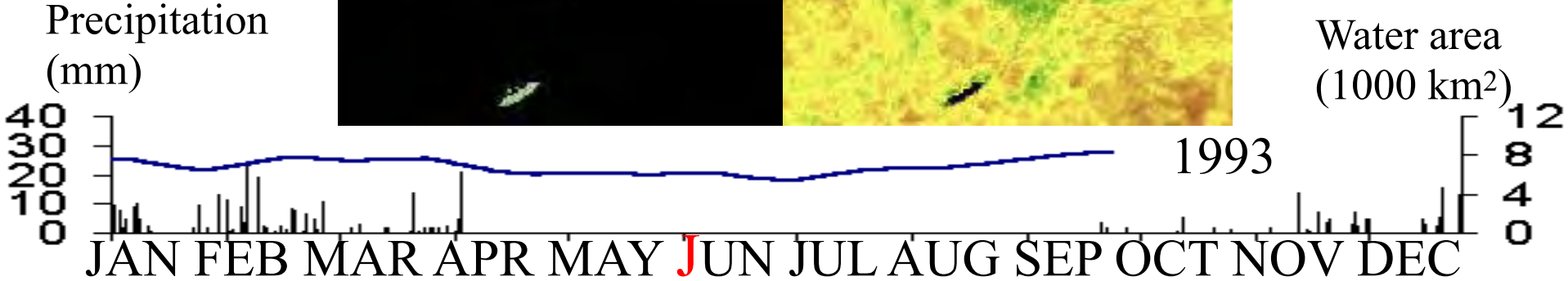




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

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NDVI

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Okavango Delta, Botswana

NOAA-AVHRR Images

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NDVI

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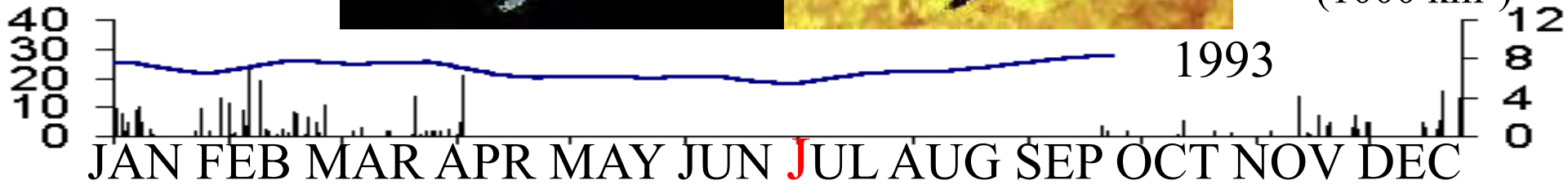
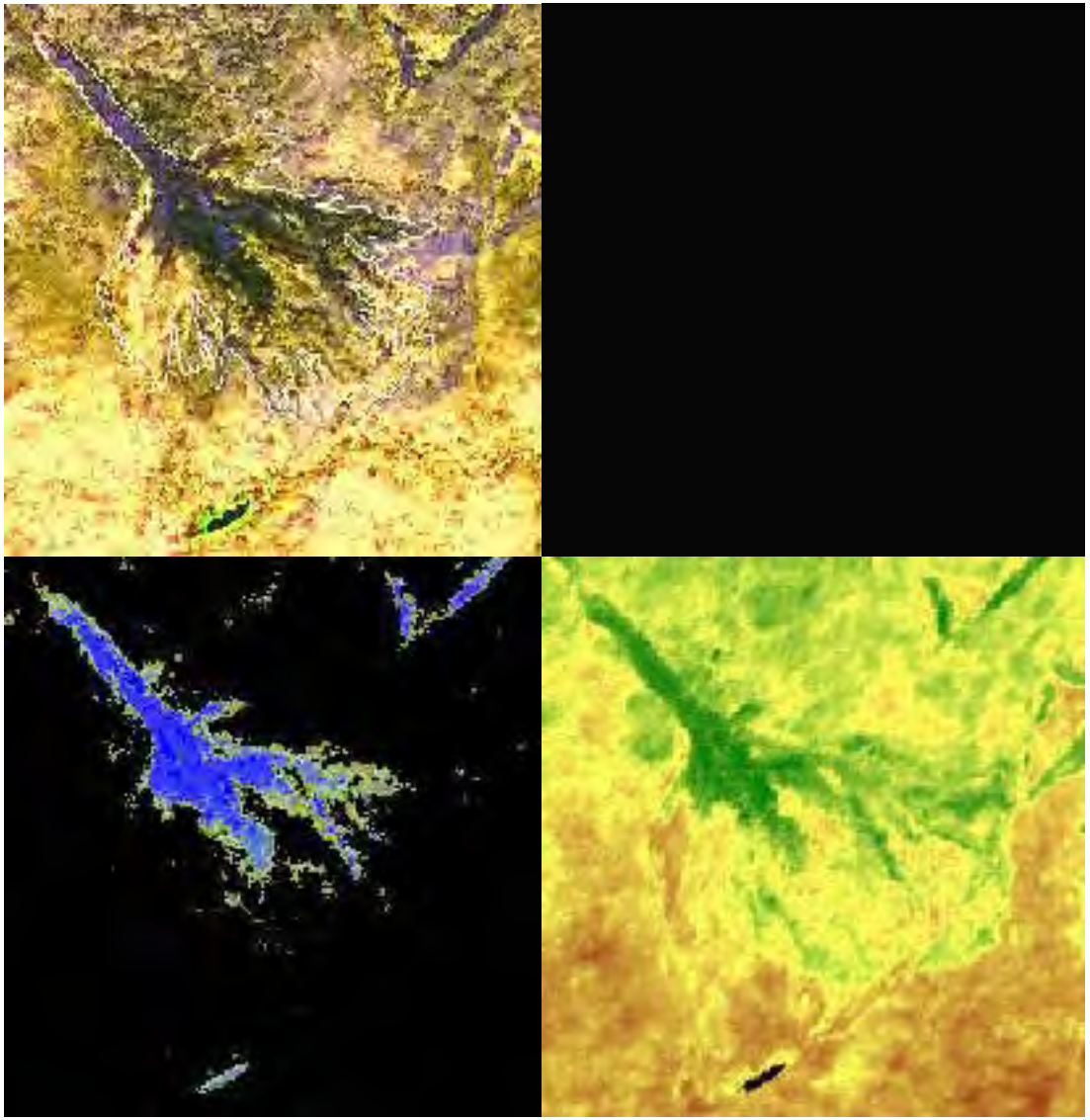
Precipitation (mm)

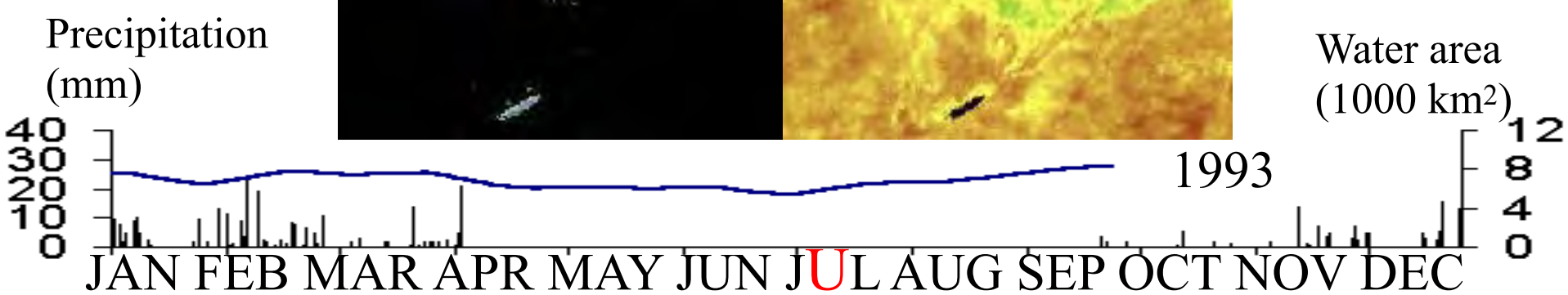
Water area (1000 km²)



Okavango Delta, Botswana

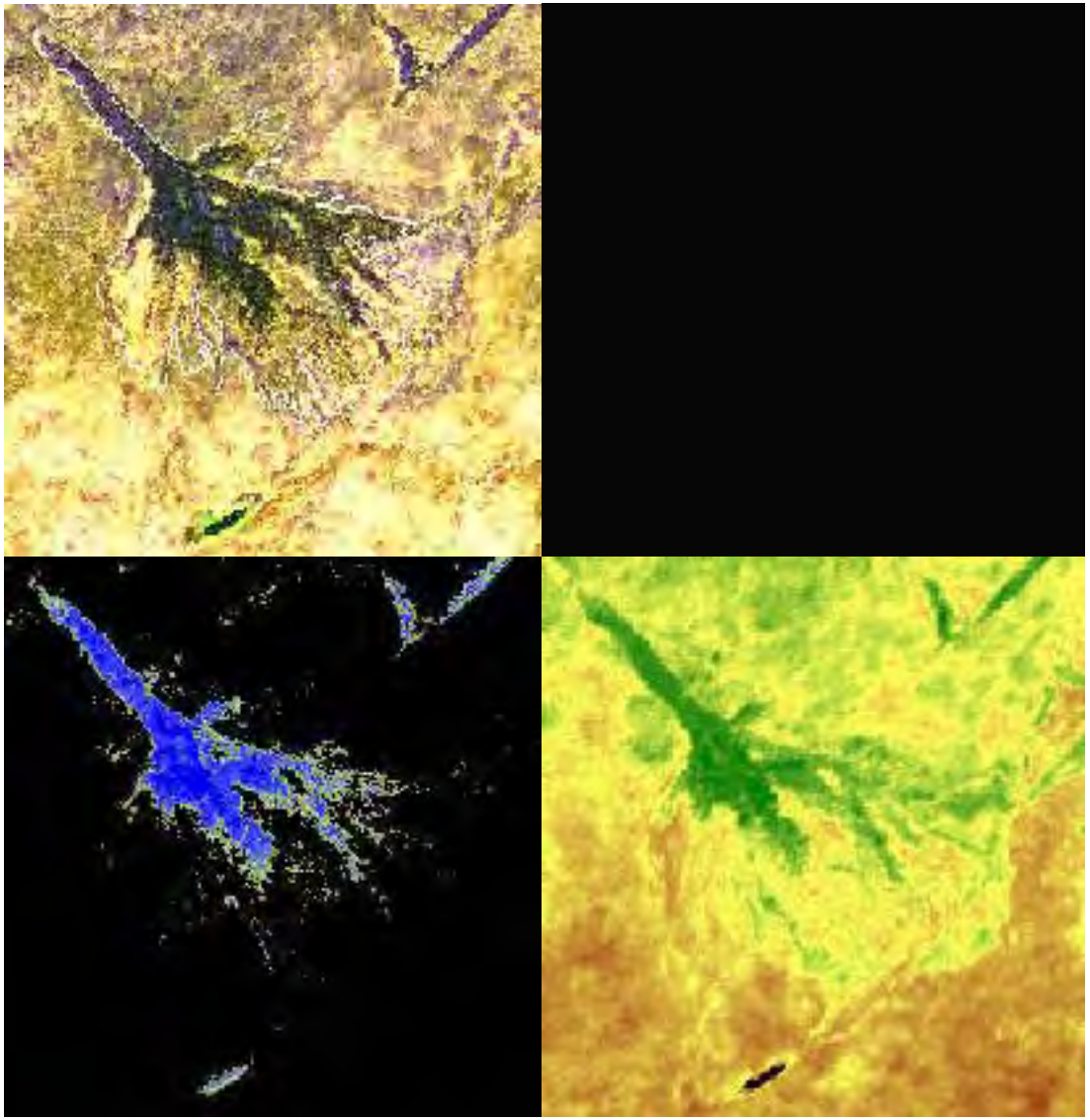
NOAA-AVHRR Images

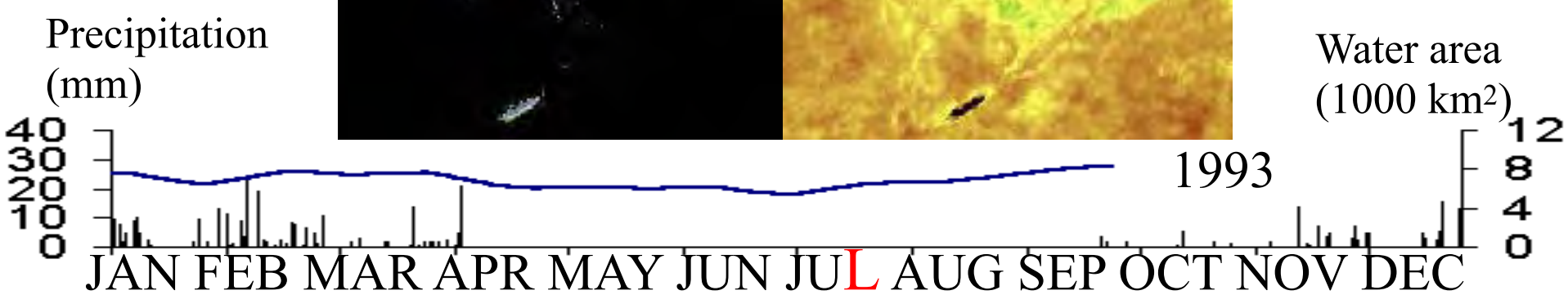




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

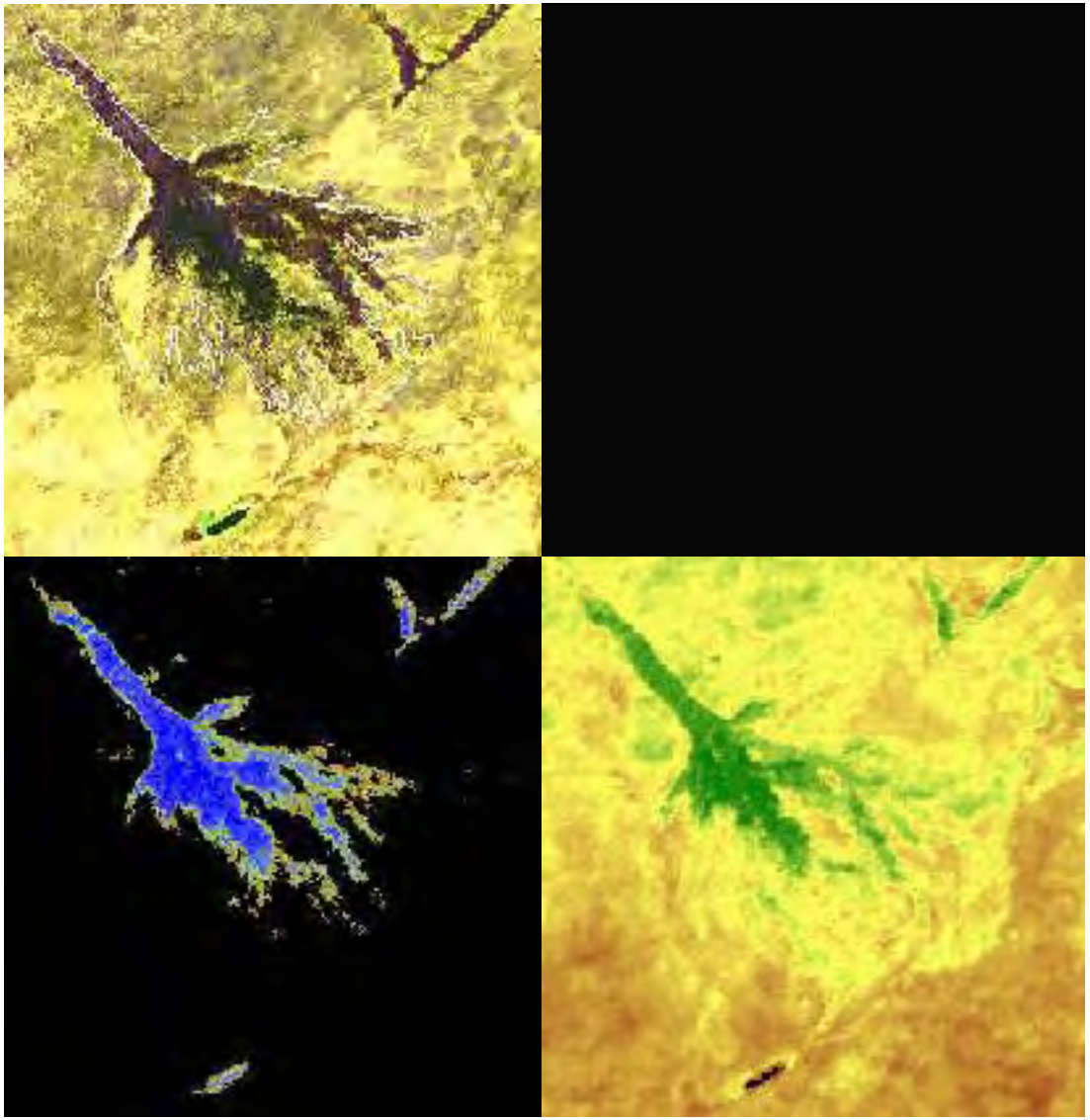
100 Km

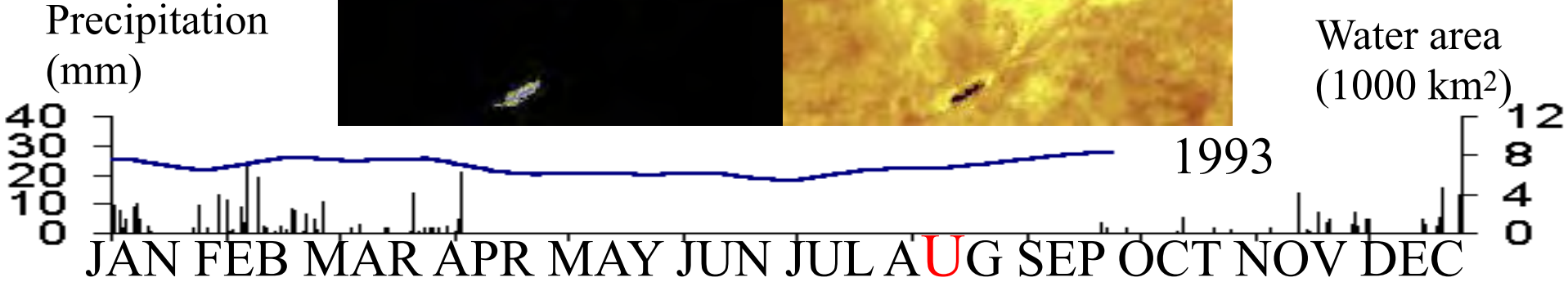
Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

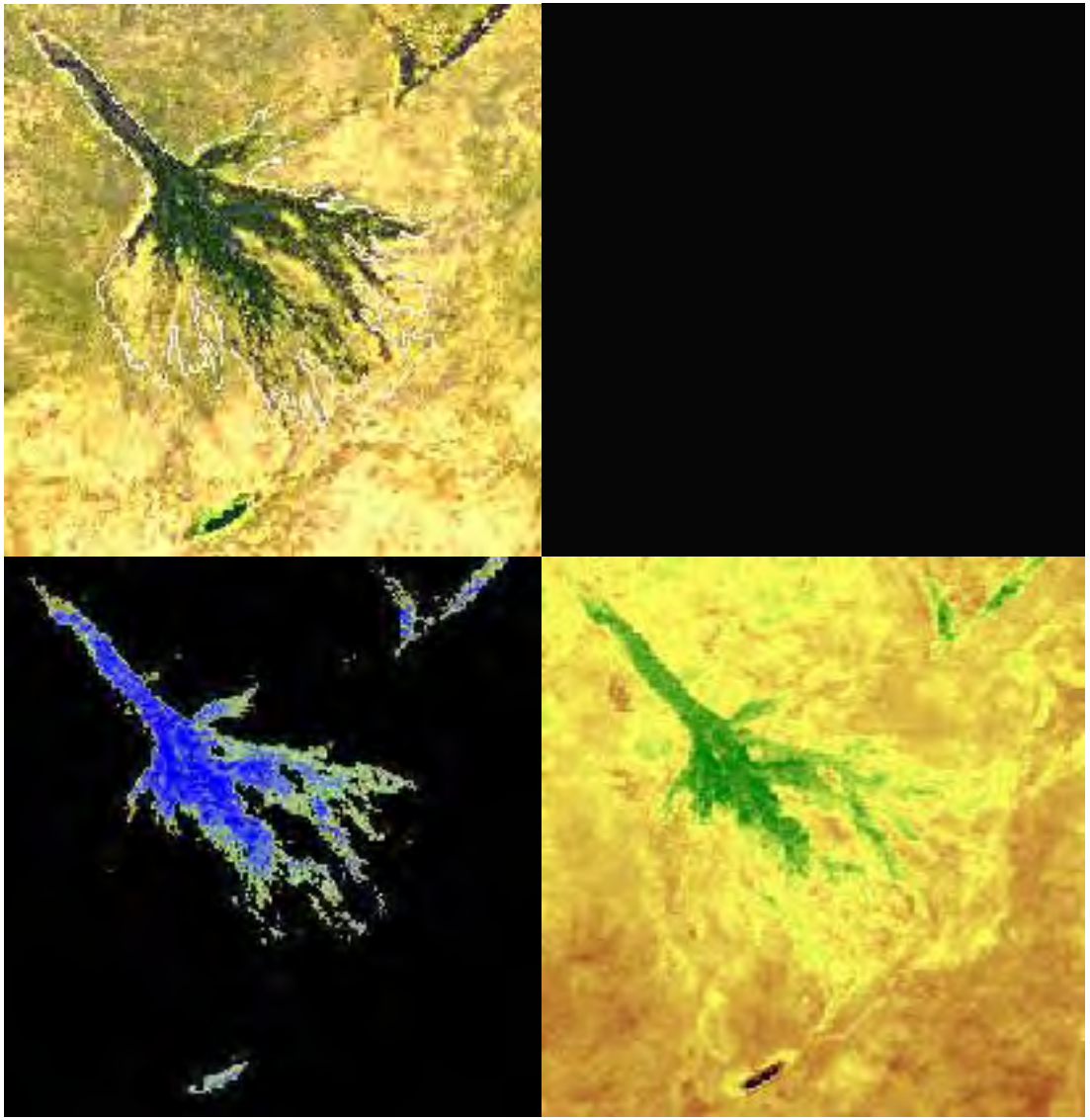
NOAA-AVHRR Images

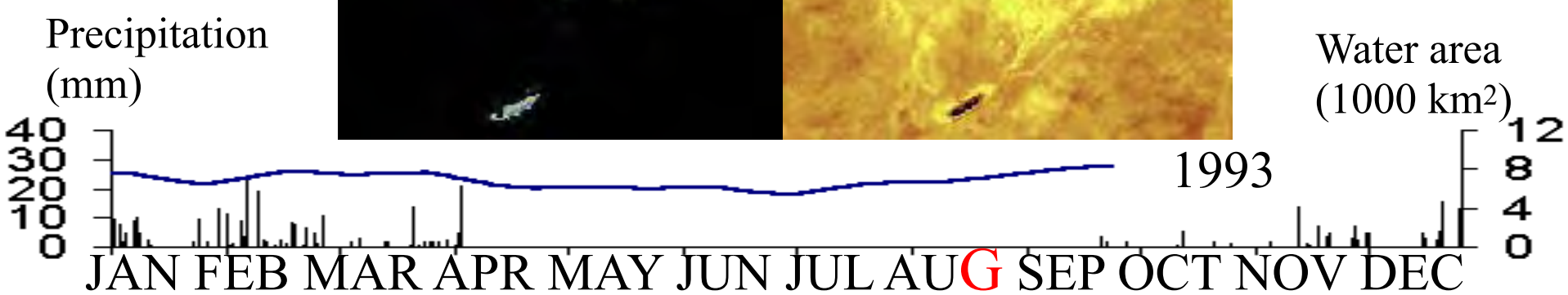




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)

Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

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Okavango Delta, Botswana

NOAA-AVHRR Images

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Water

NDVI

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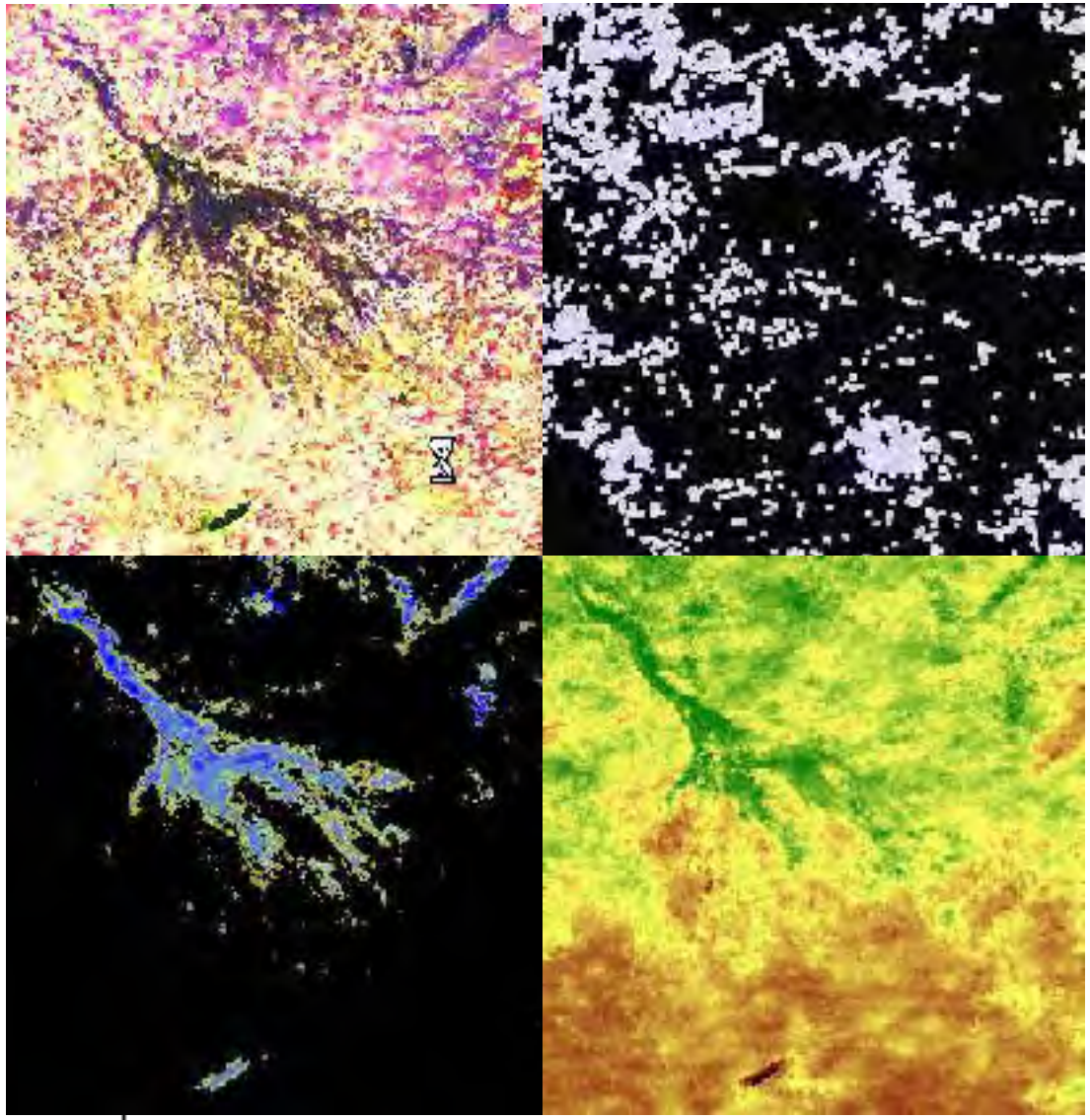
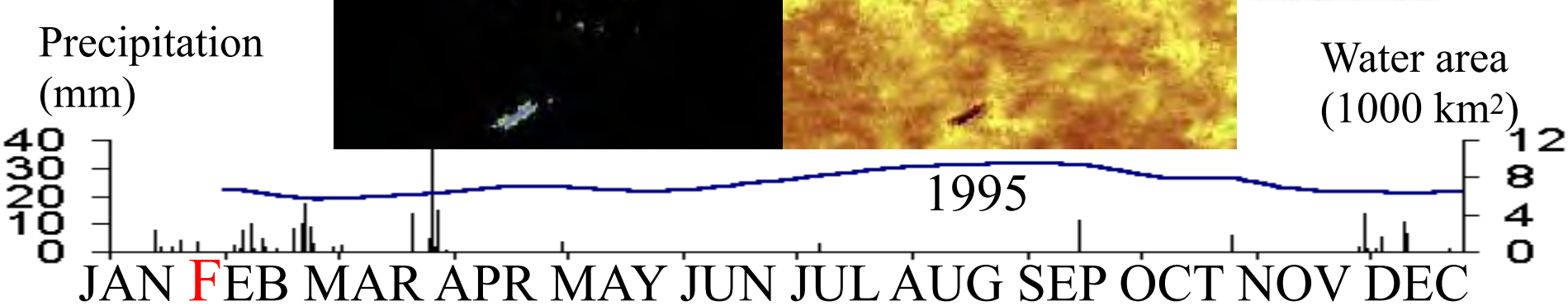
Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

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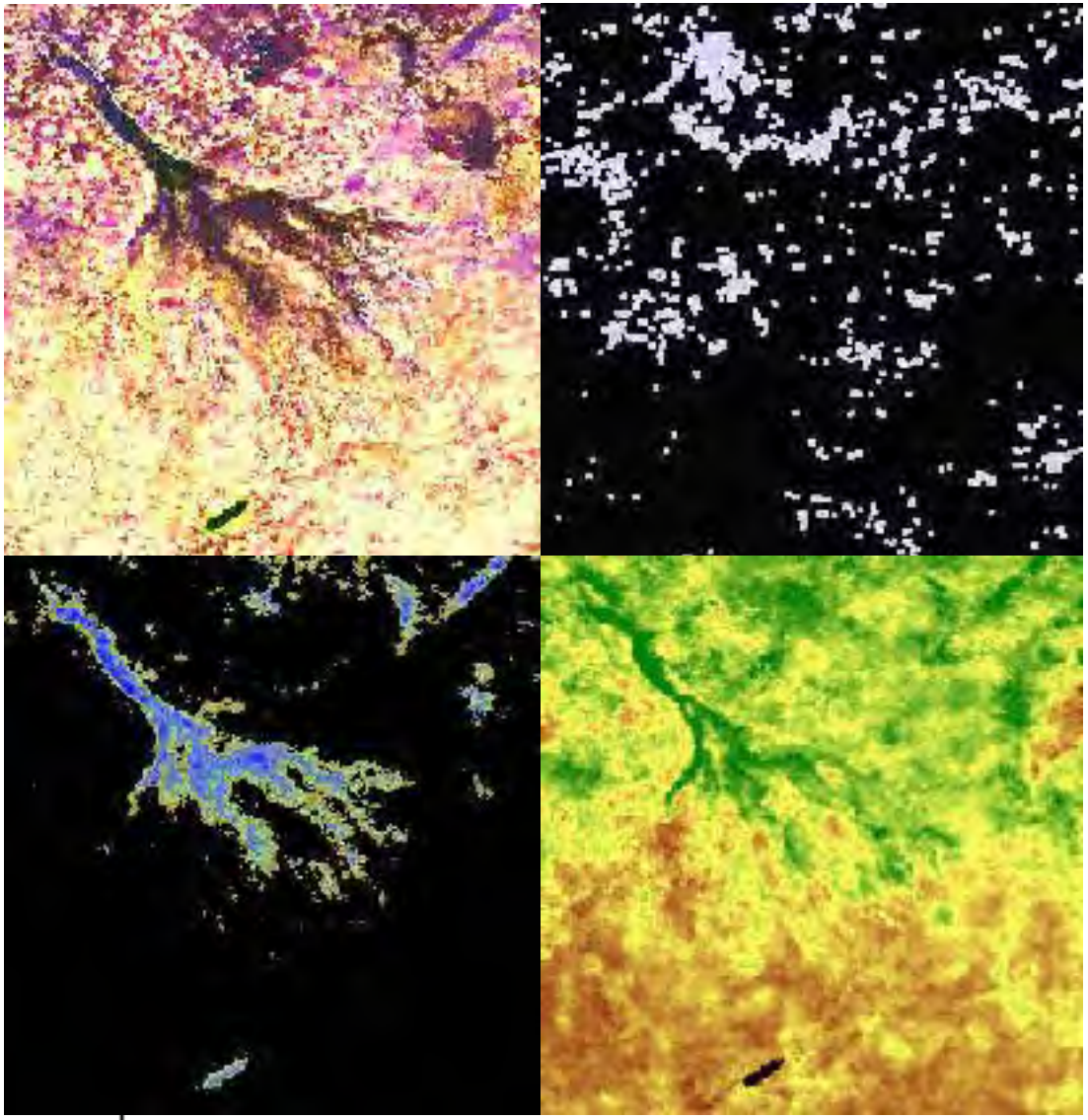
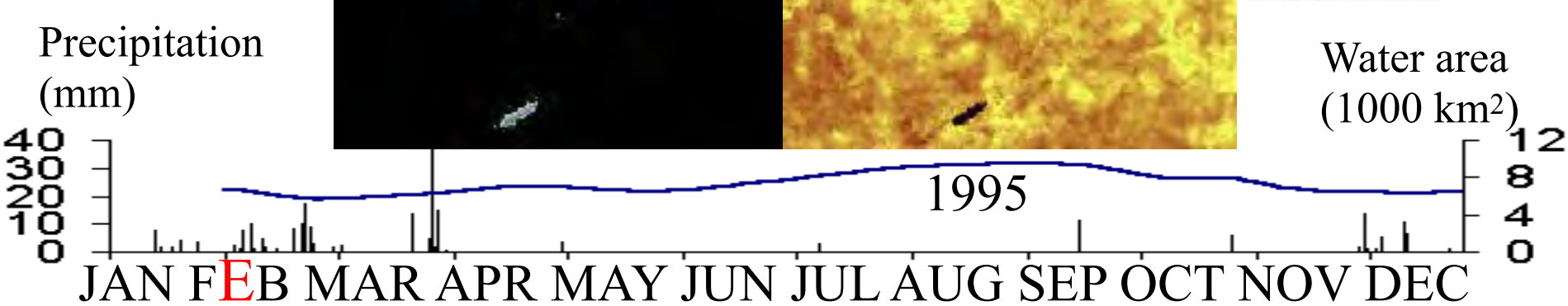
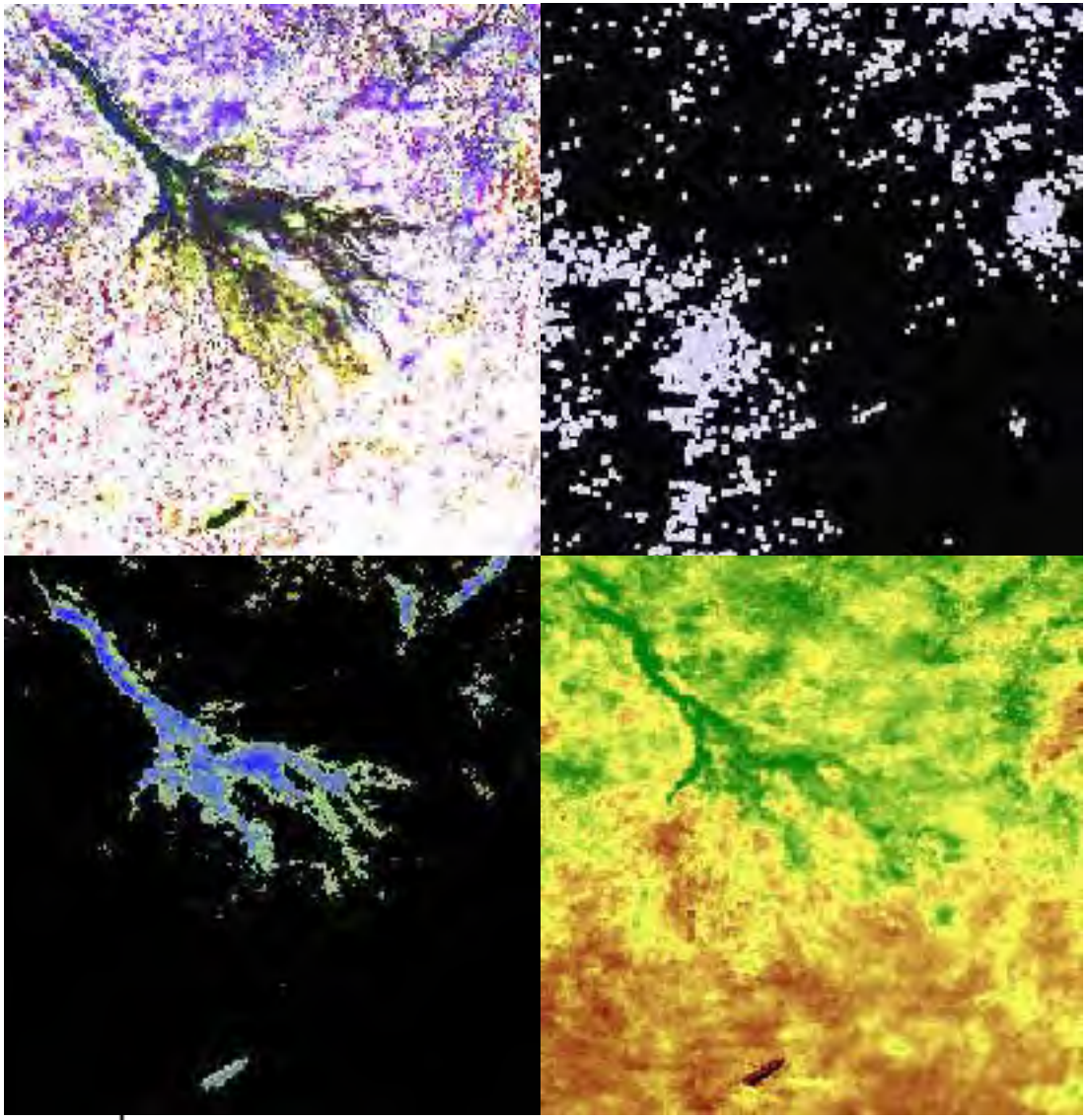
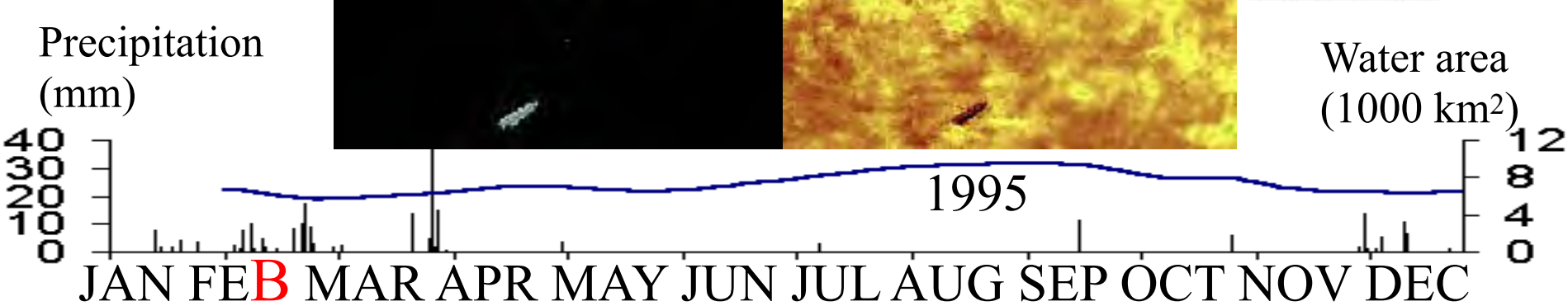




Okavango Delta, Botswana

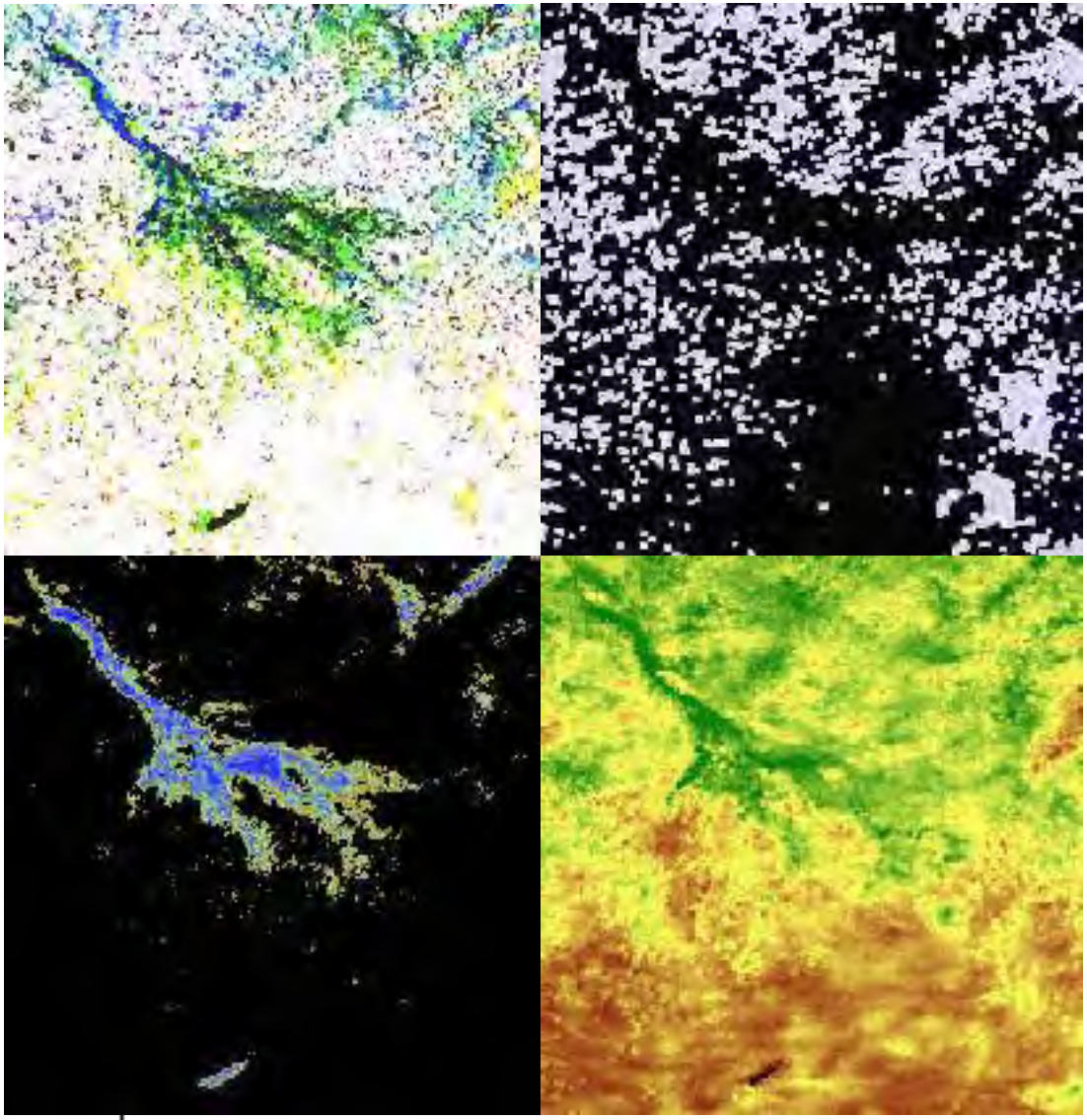
NOAA-AVHRR Images

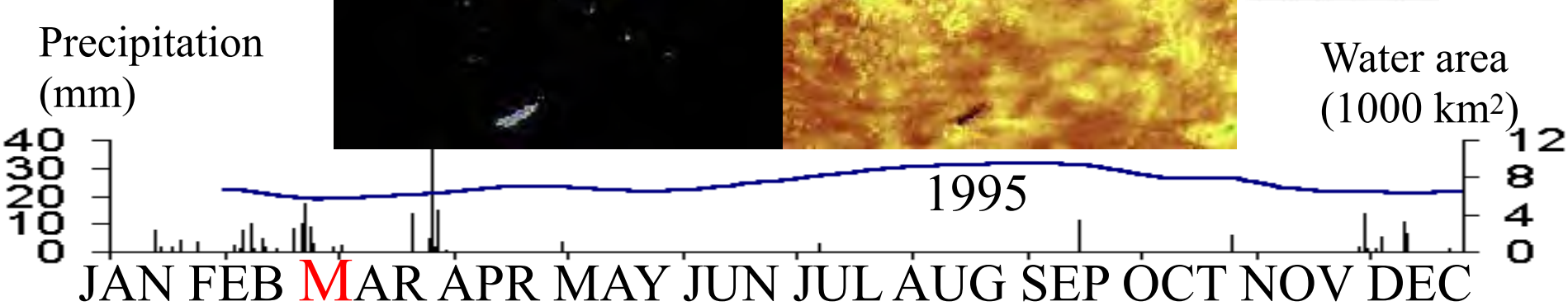




Okavango Delta, Botswana

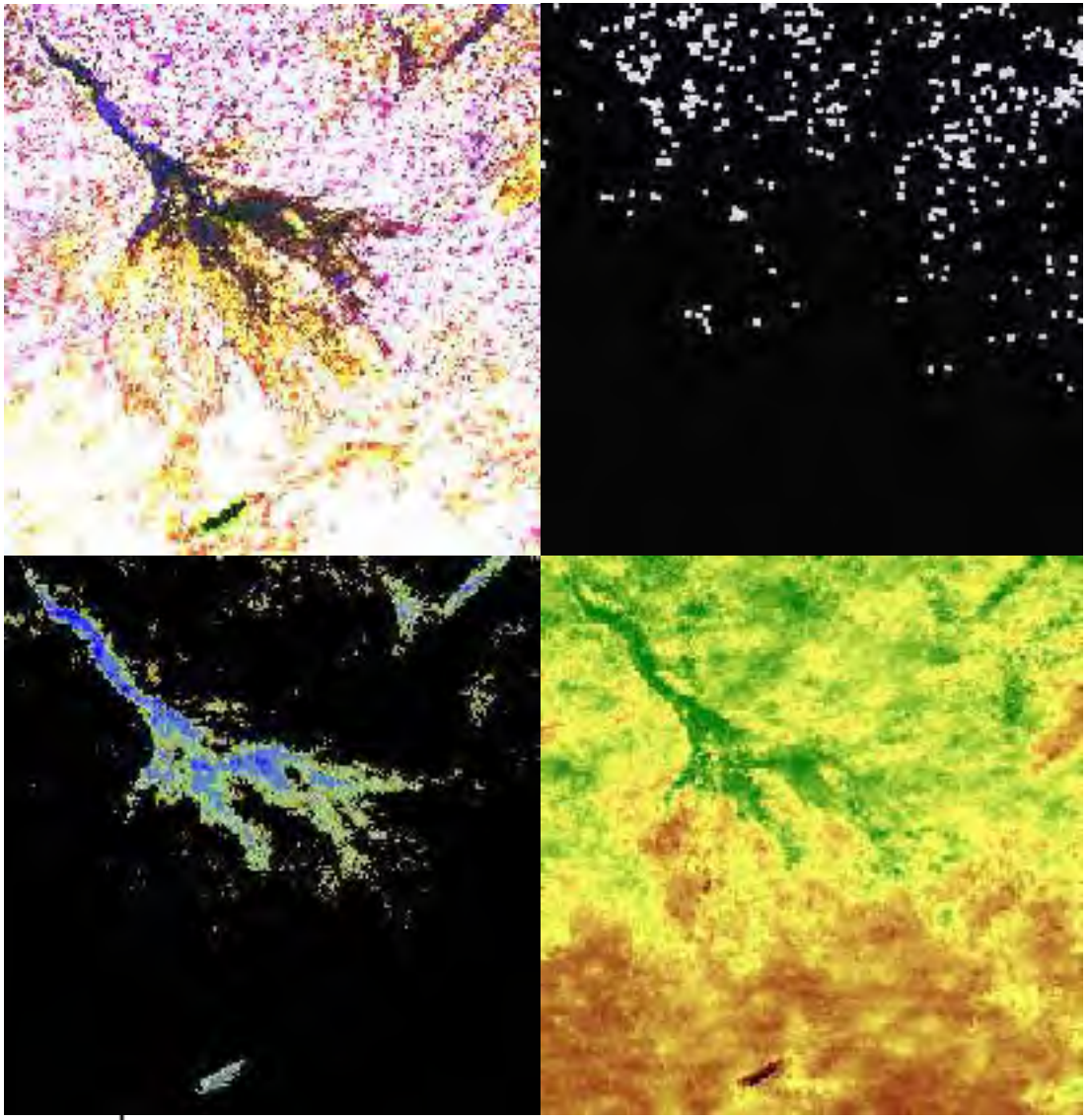
NOAA-AVHRR Images

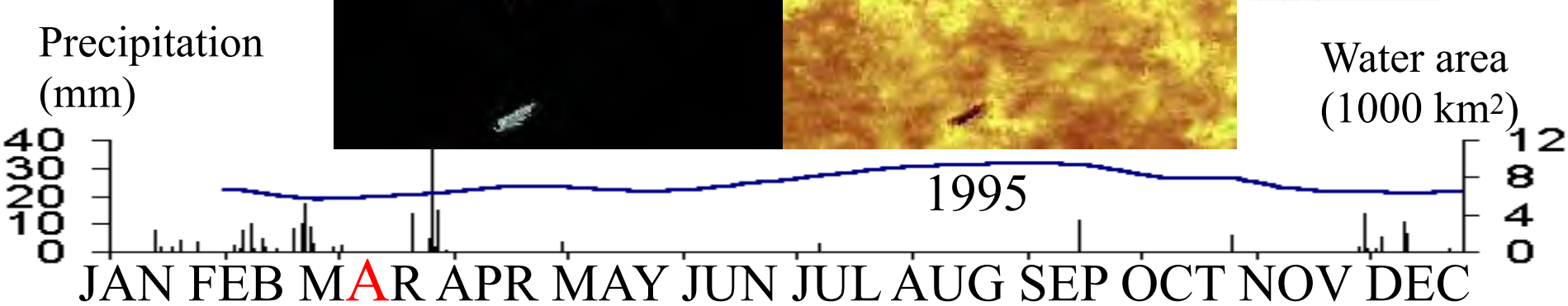




Okavango Delta, Botswana

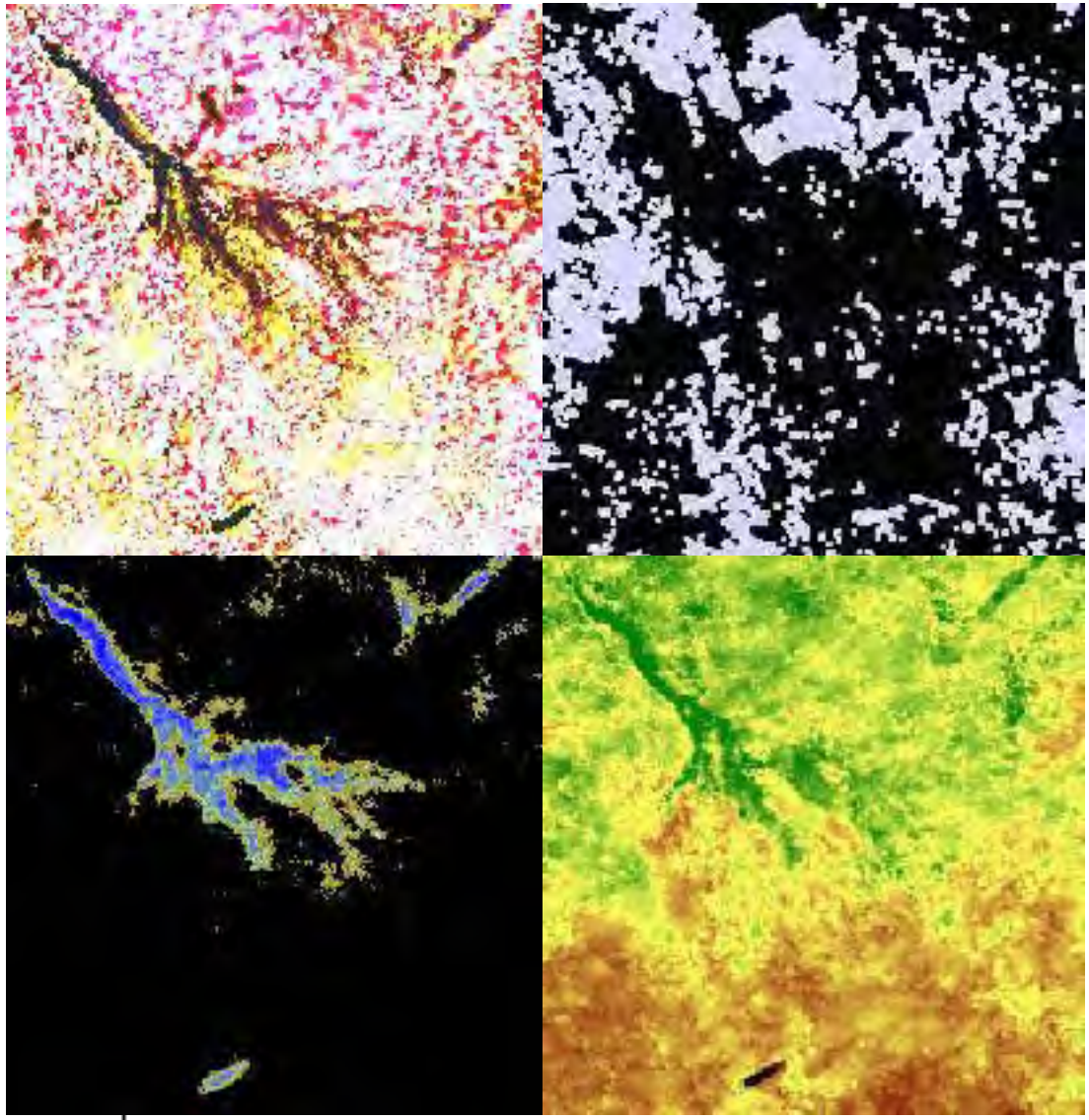
NOAA-AVHRR Images

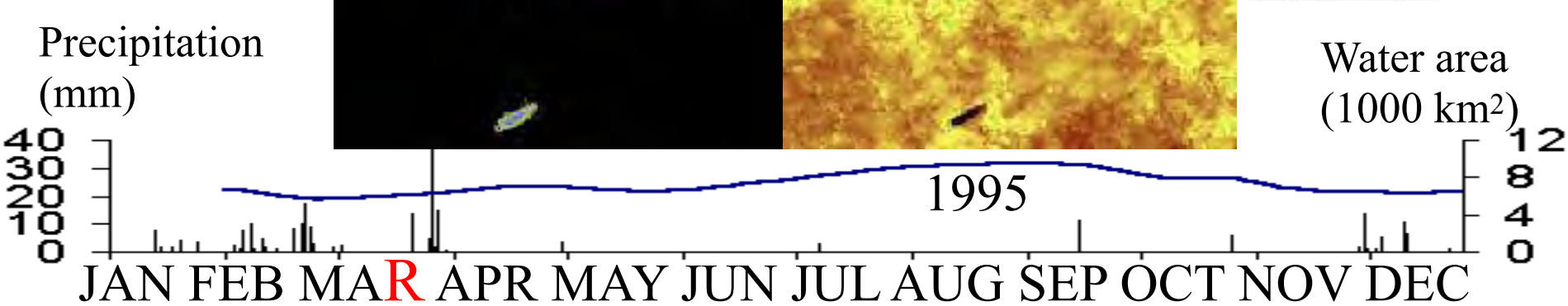




Okavango Delta, Botswana

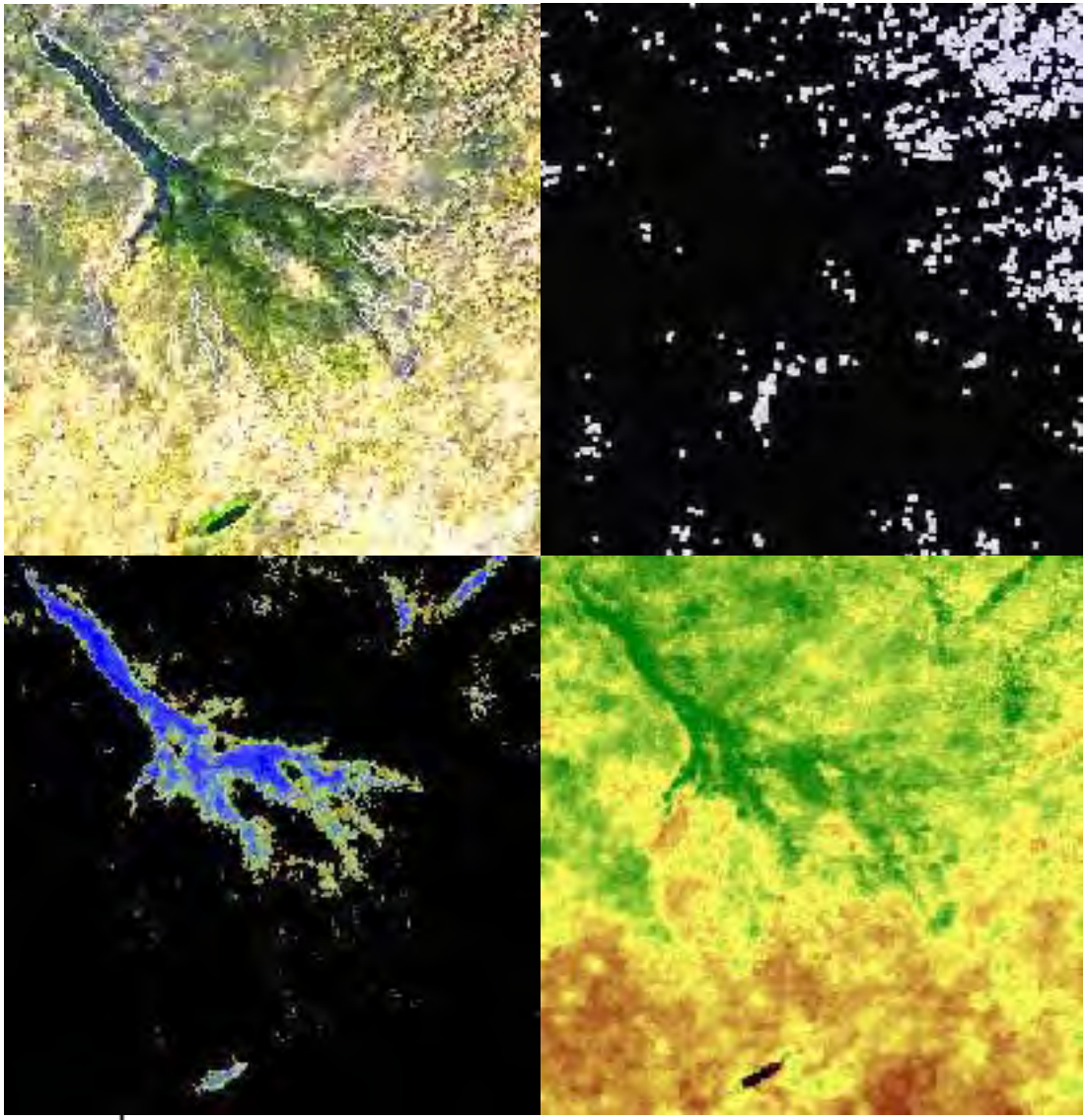
NOAA-AVHRR Images

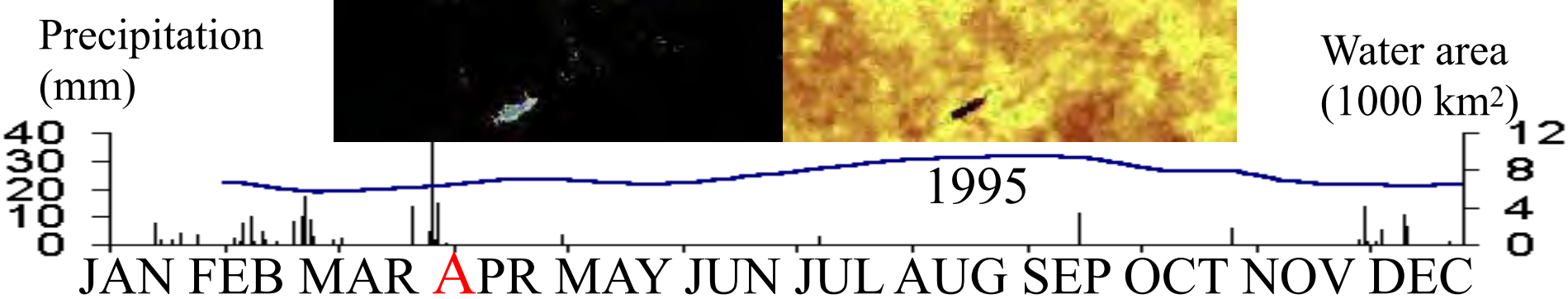




Okavango Delta, Botswana

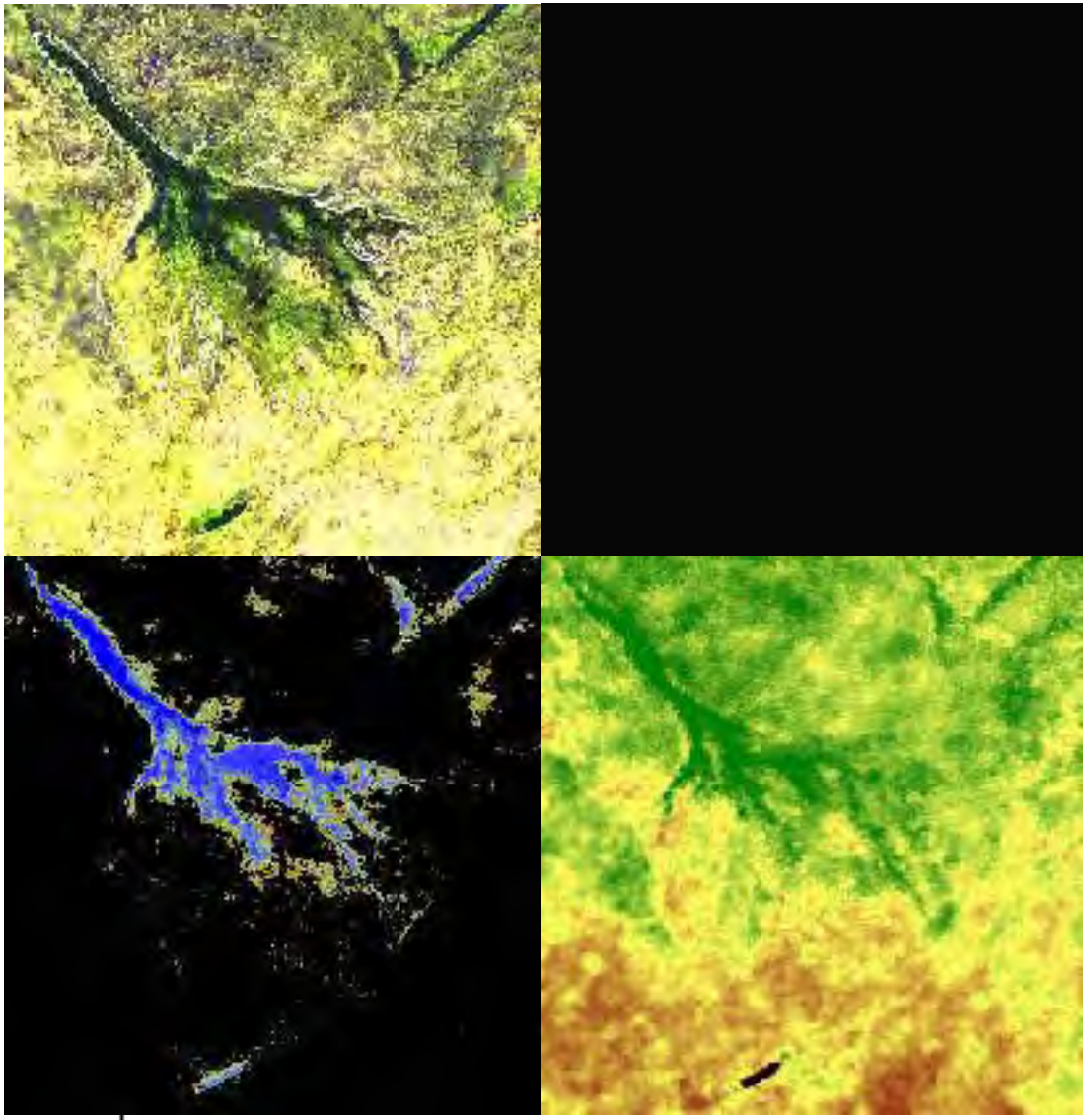
NOAA-AVHRR Images

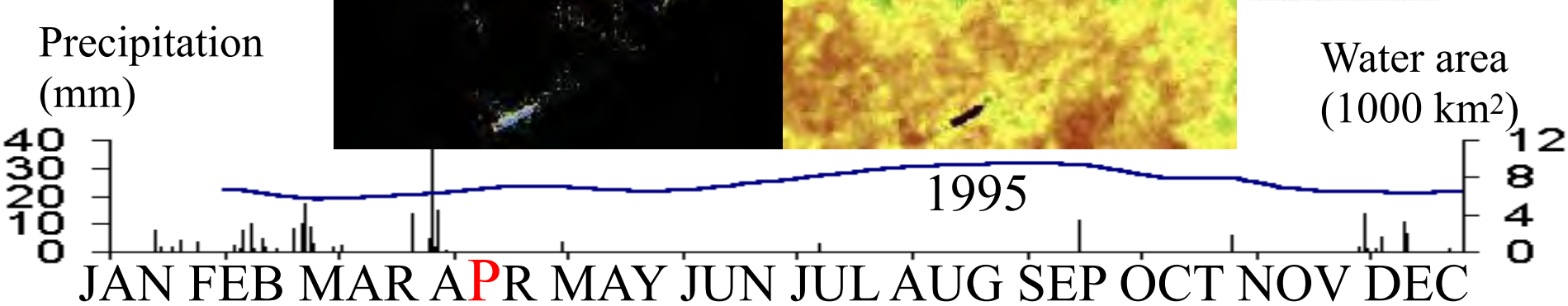




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

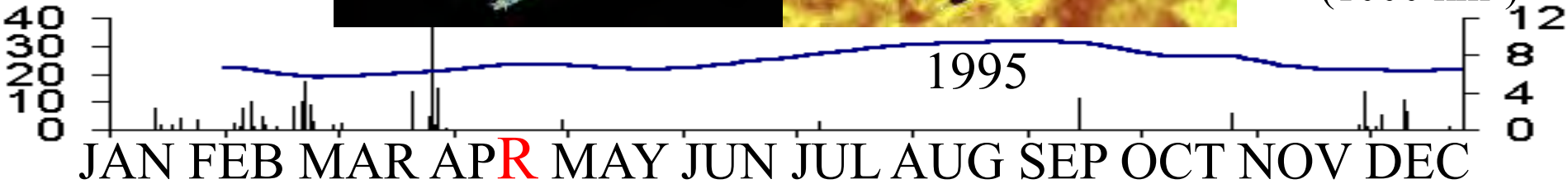
NDVI

N

100 Km

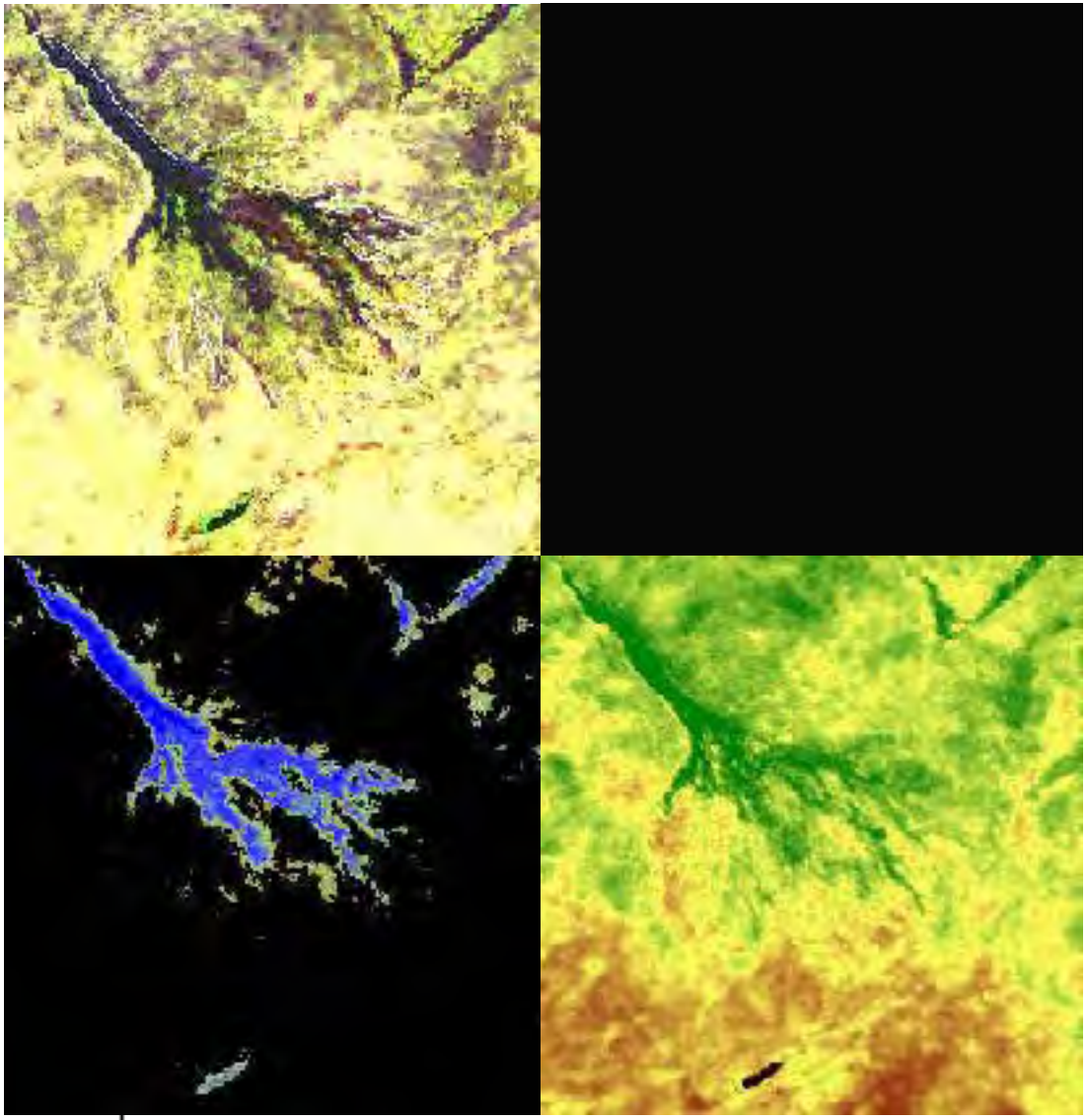
Precipitation (mm)

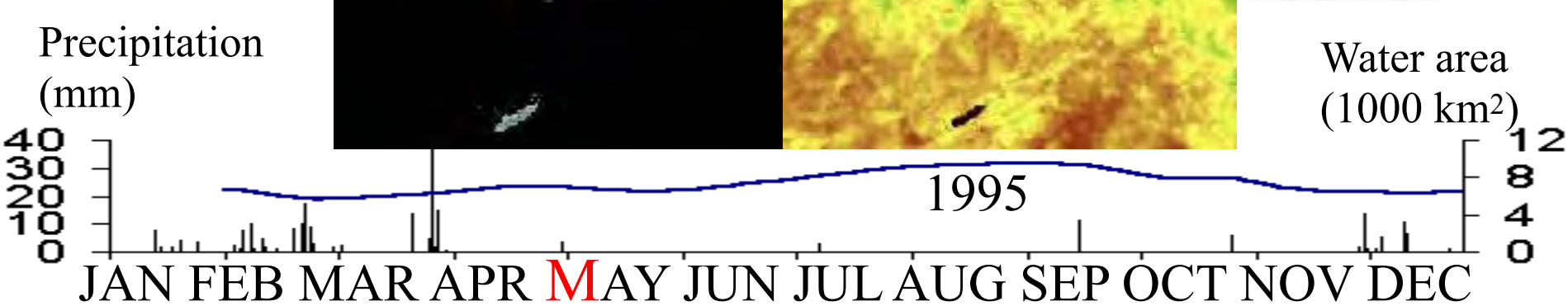
Water area (1000 km²)



Okavango Delta, Botswana

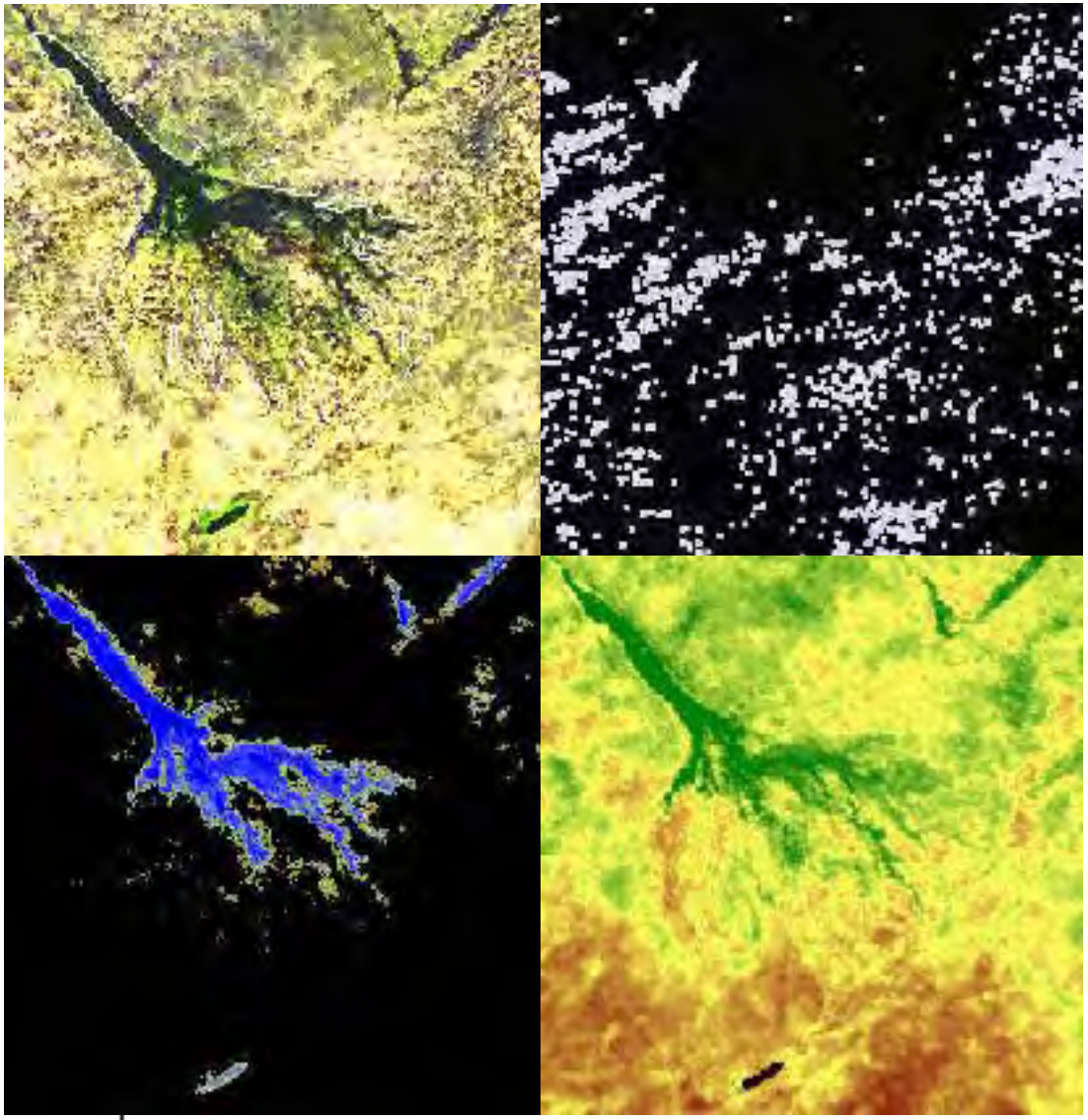
NOAA-AVHRR Images

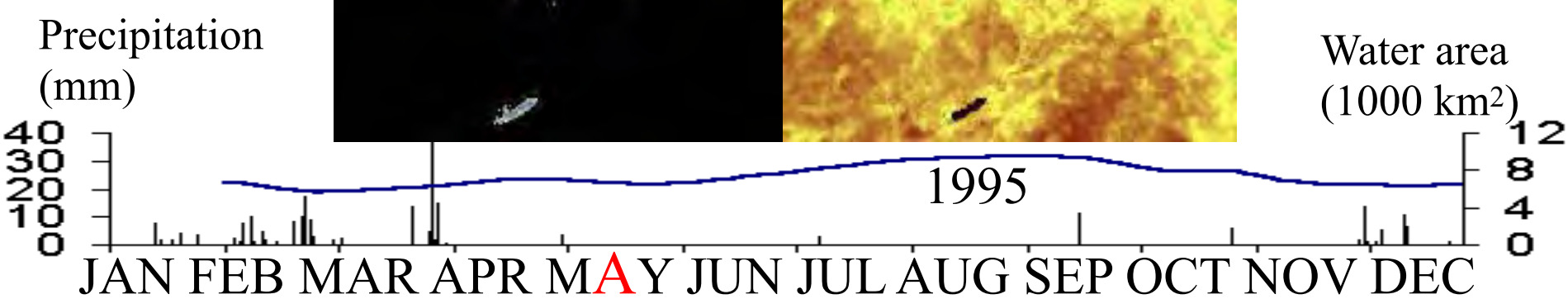




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

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NDVI

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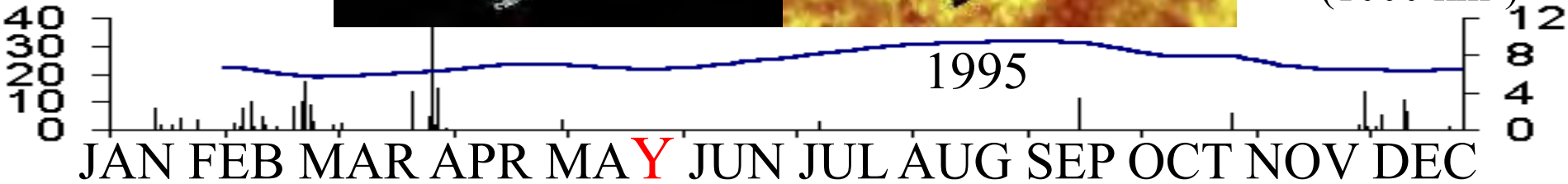
100 Km

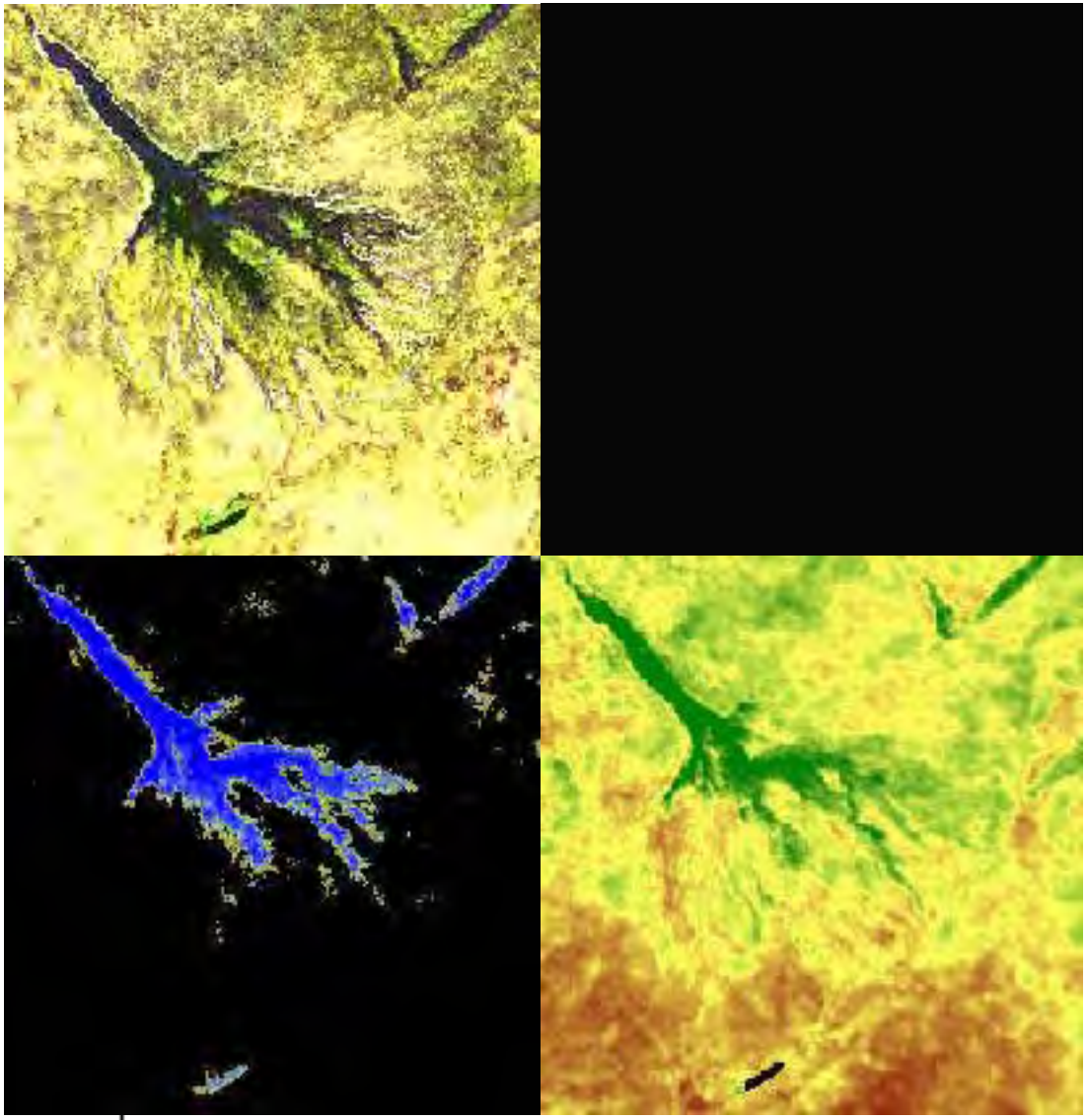
Precipitation (mm)

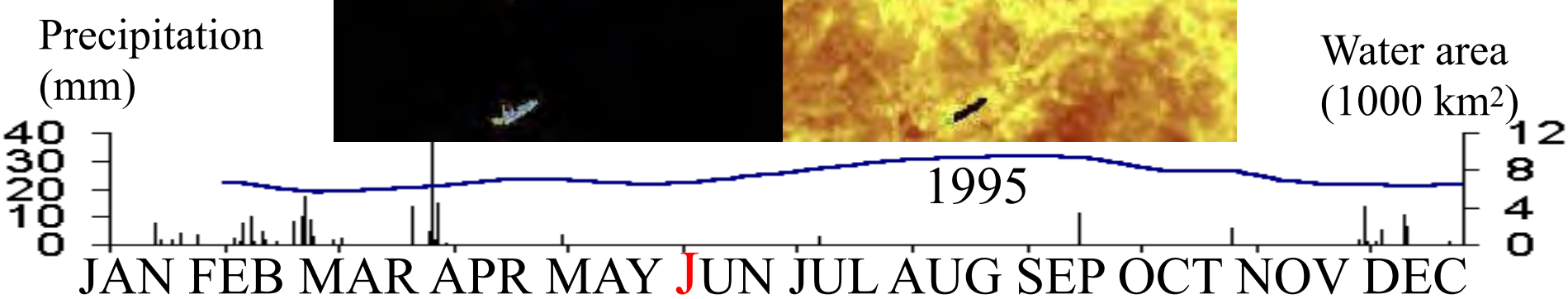
Water area (1000 km²)



Okavango Delta, Botswana

NOAA-AVHRR Images





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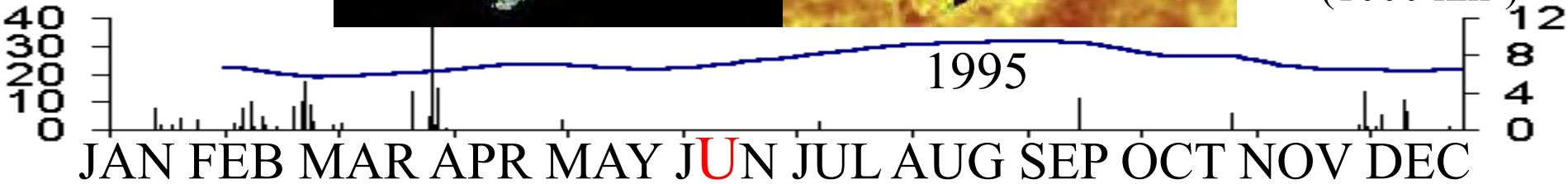
Precipitation (mm)

Water area (1000 km²)



Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

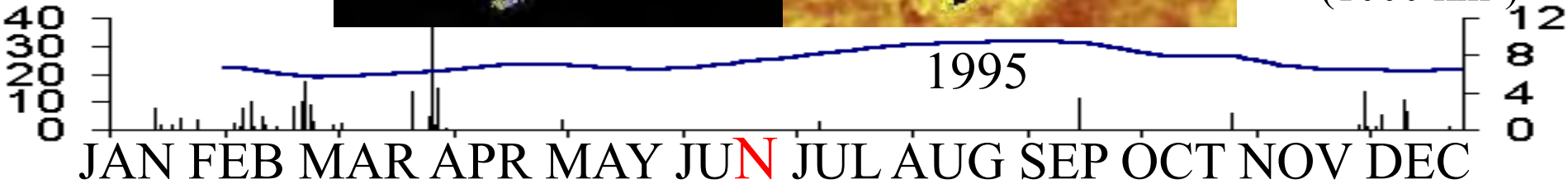
NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)



Okavango Delta, Botswana

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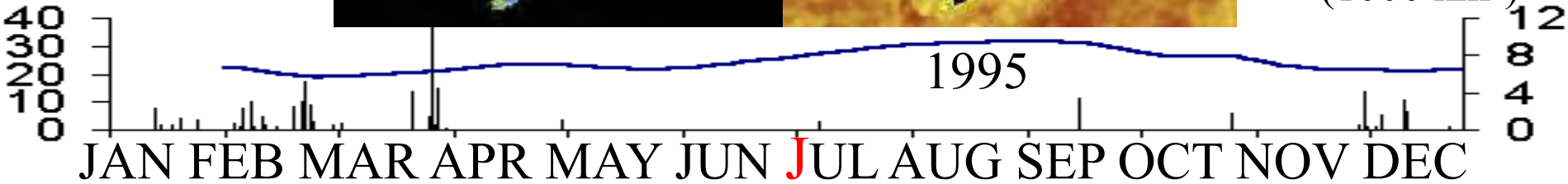
N

100 Km

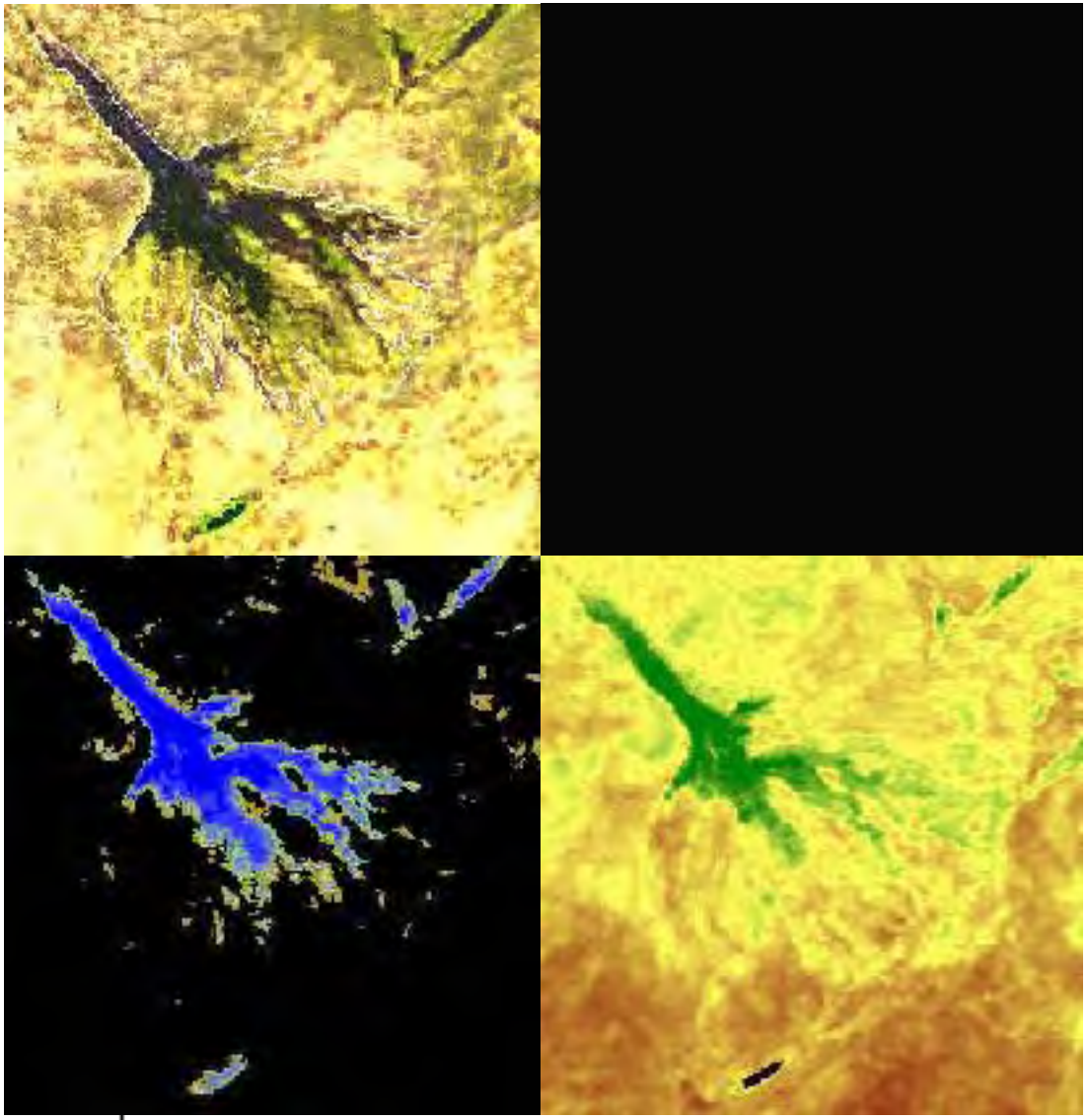
Precipitation (mm)

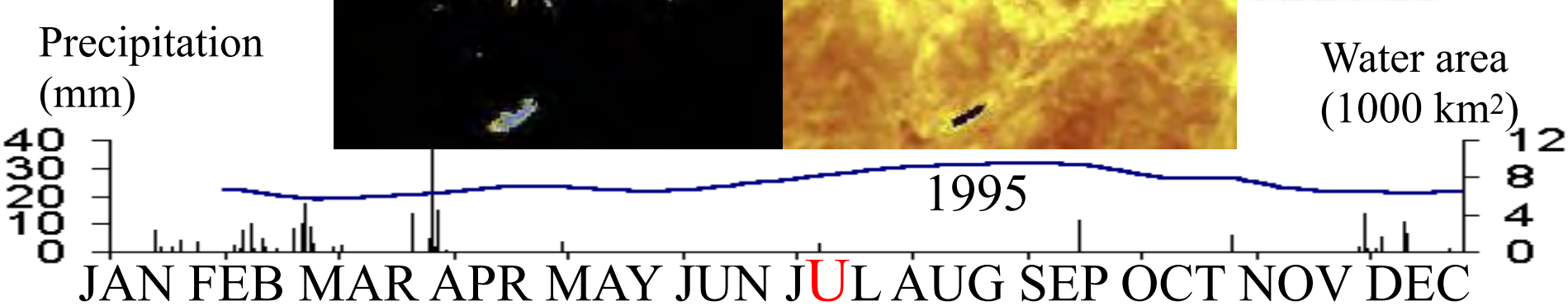
Water area (1000 km²)



Okavango Delta, Botswana

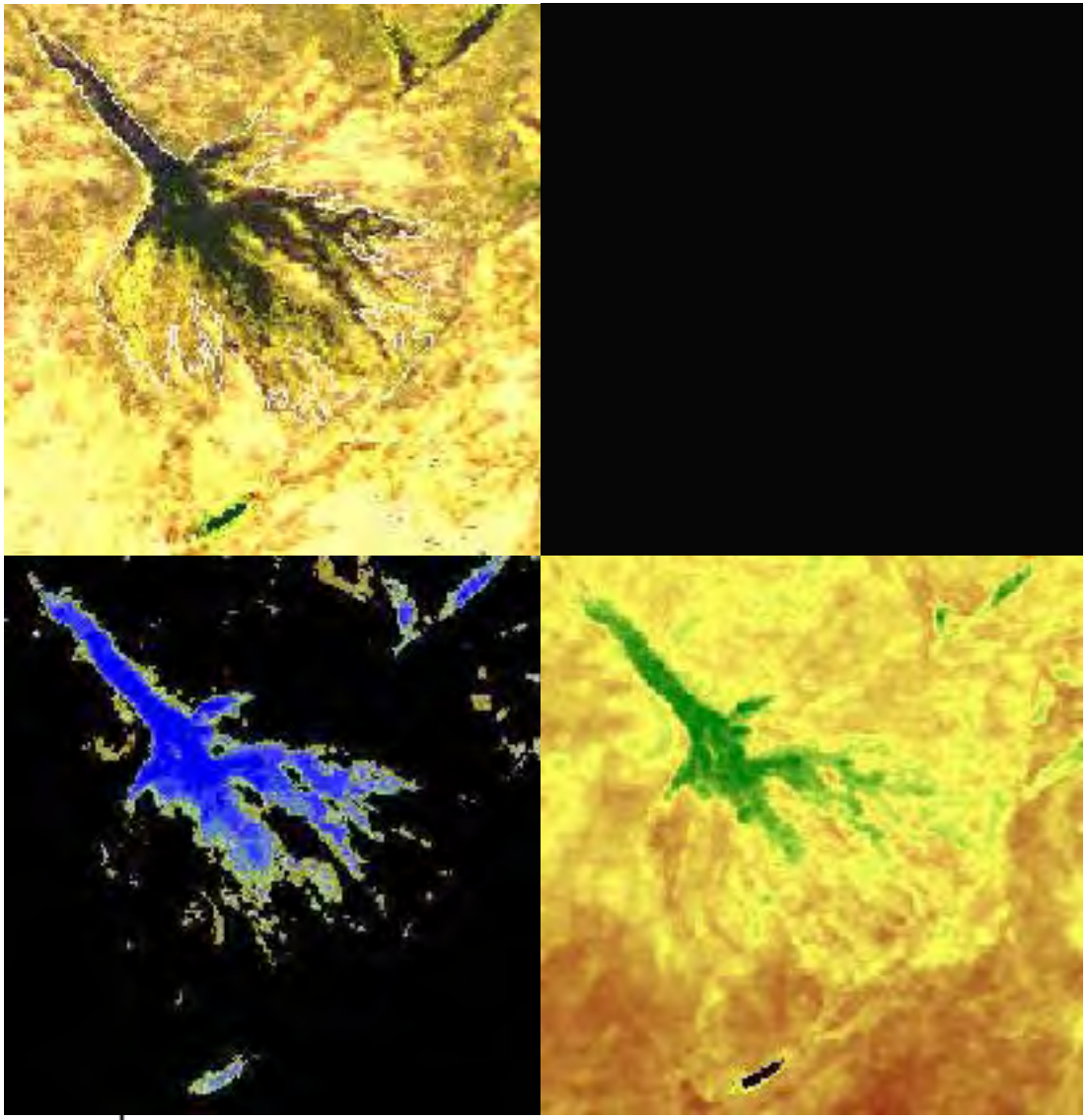
NOAA-AVHRR Images

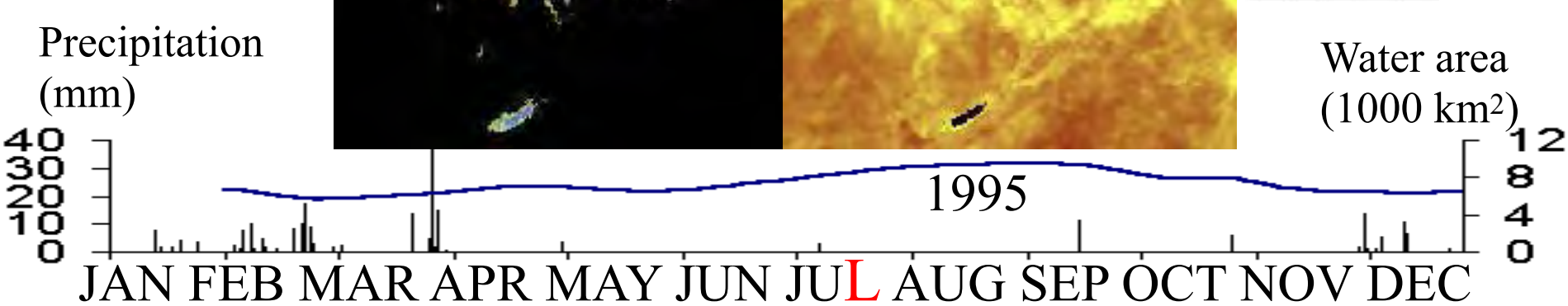




Okavango Delta, Botswana

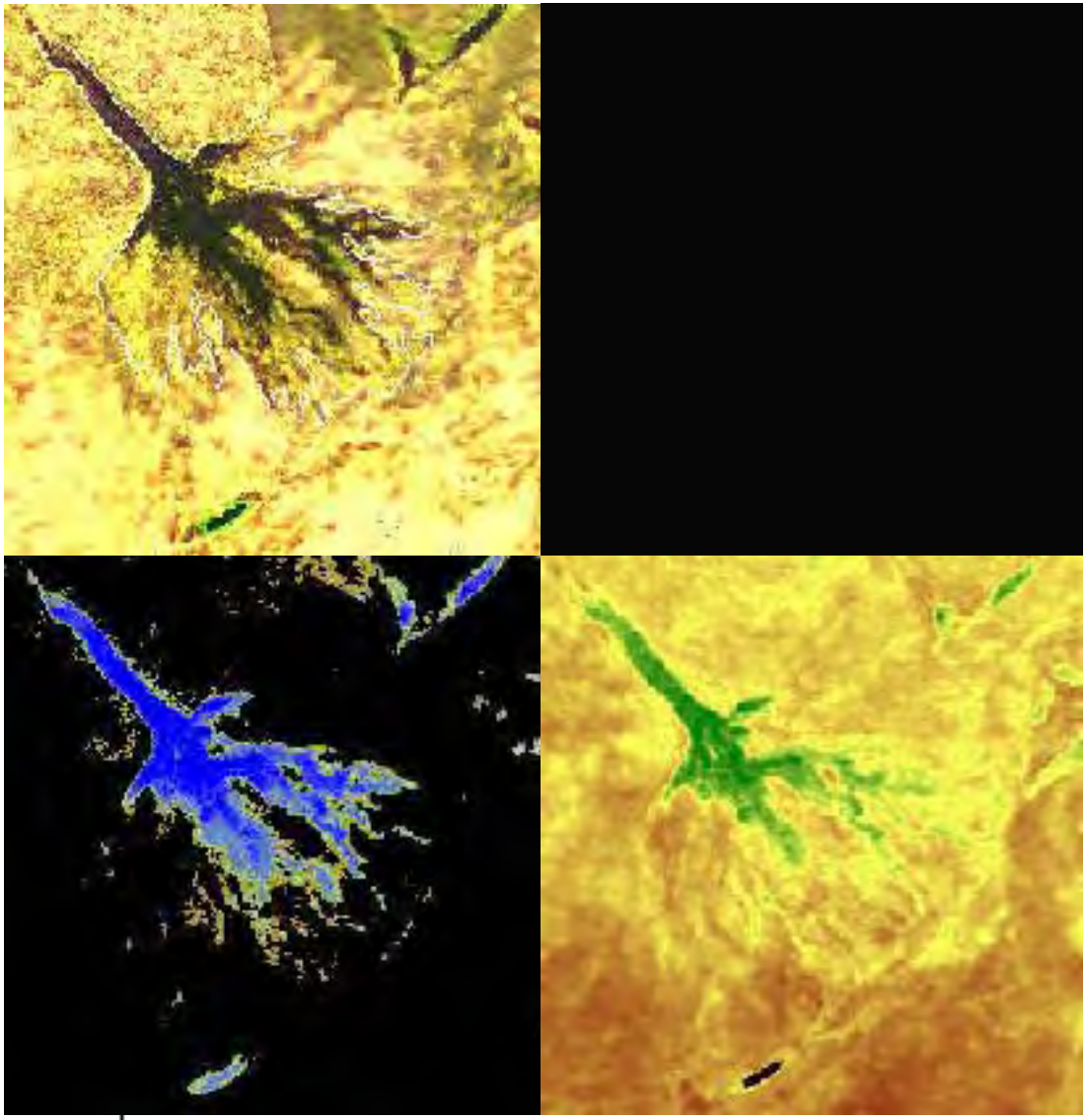
NOAA-AVHRR Images

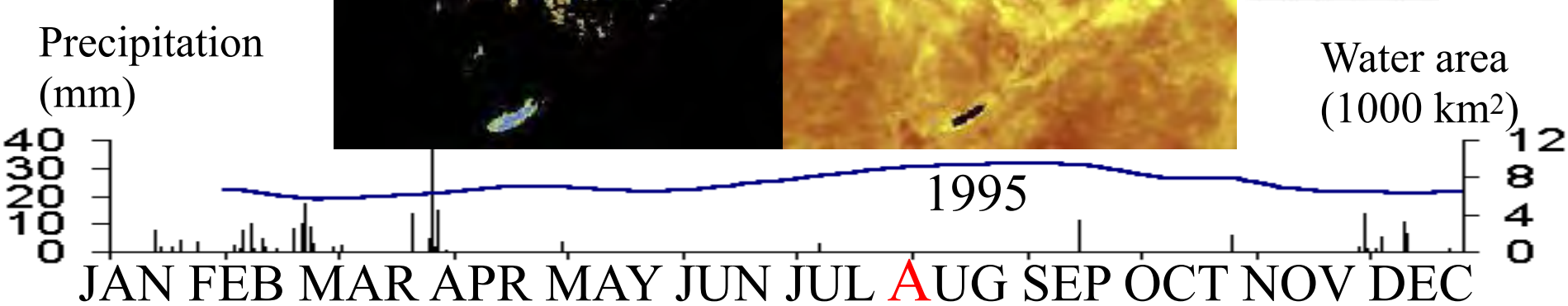




Okavango Delta, Botswana

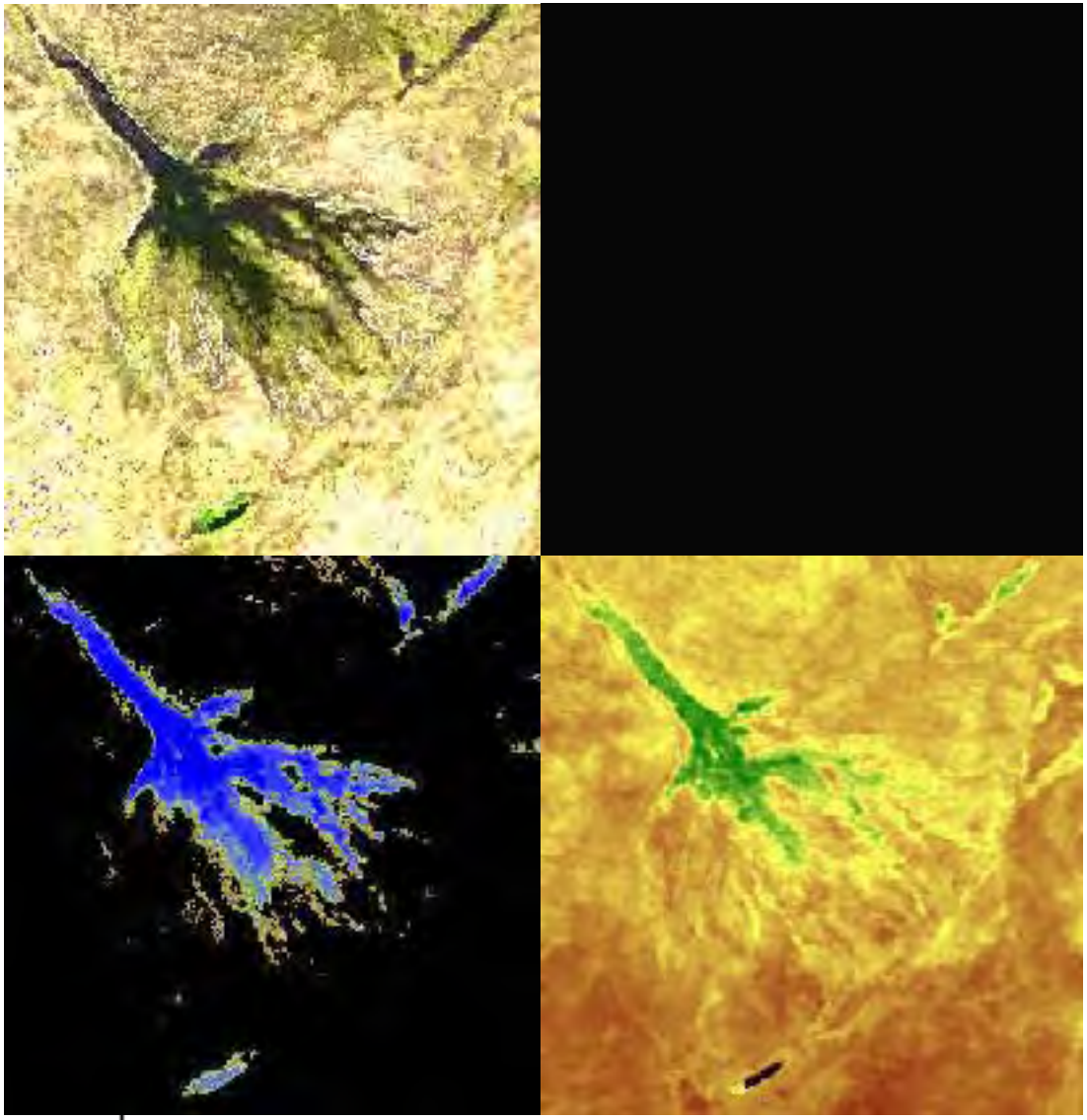
NOAA-AVHRR Images

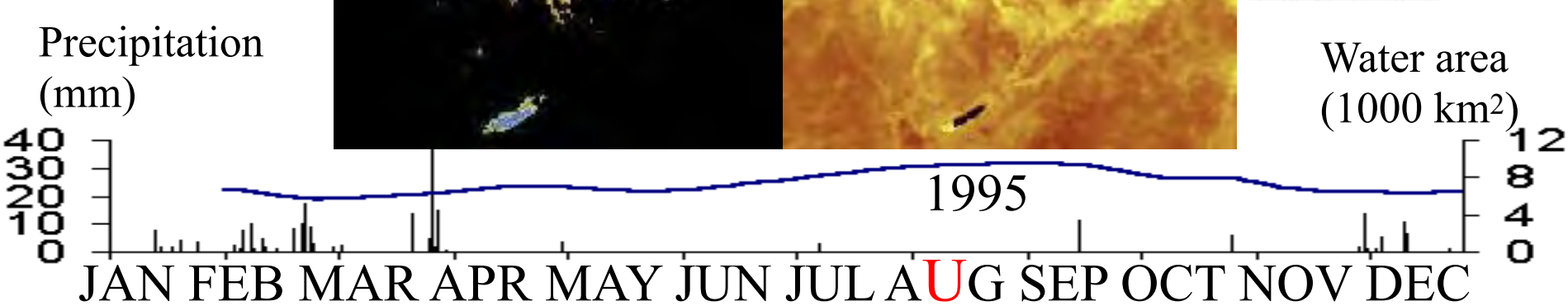




Okavango Delta, Botswana

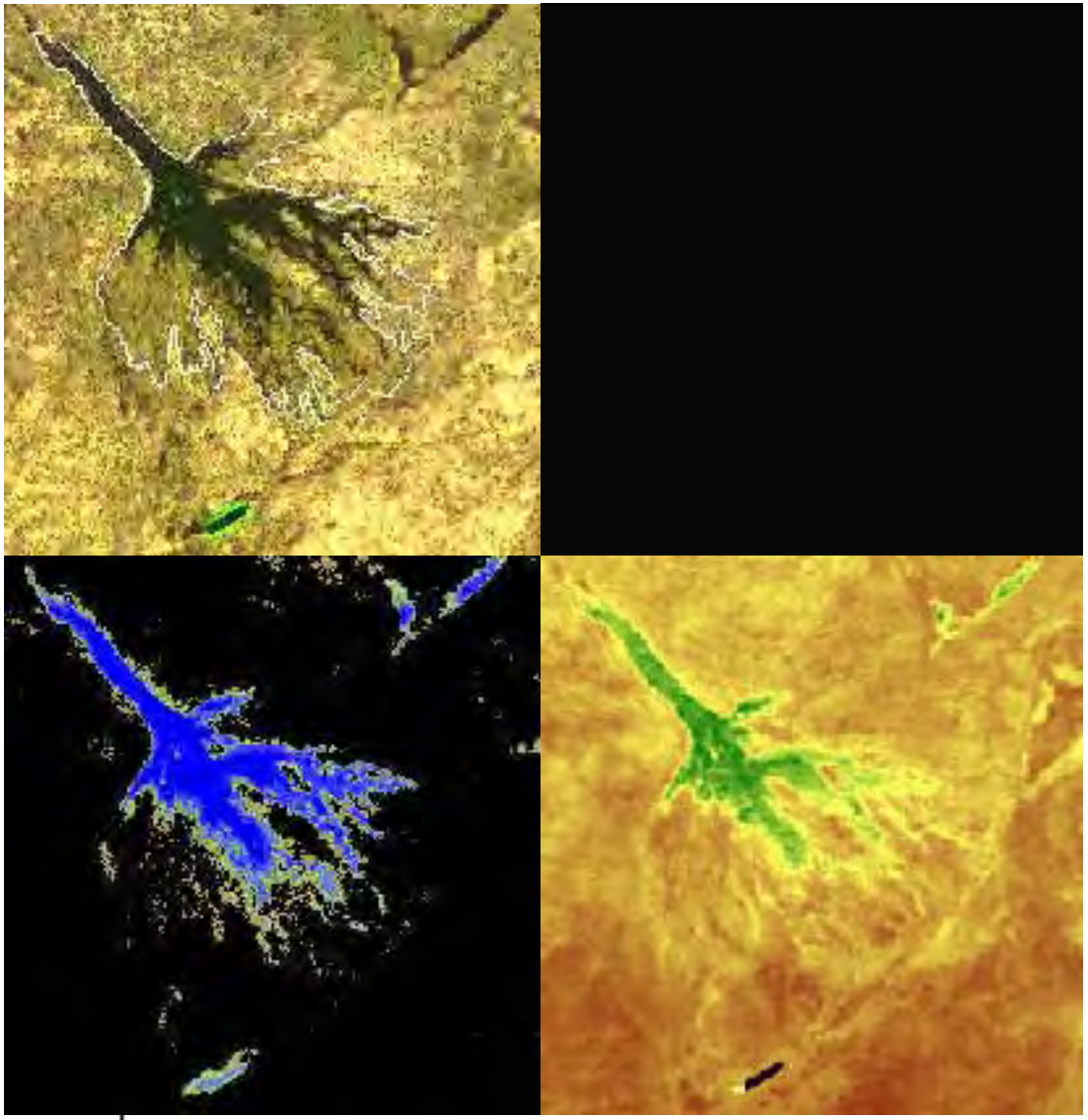
NOAA-AVHRR Images

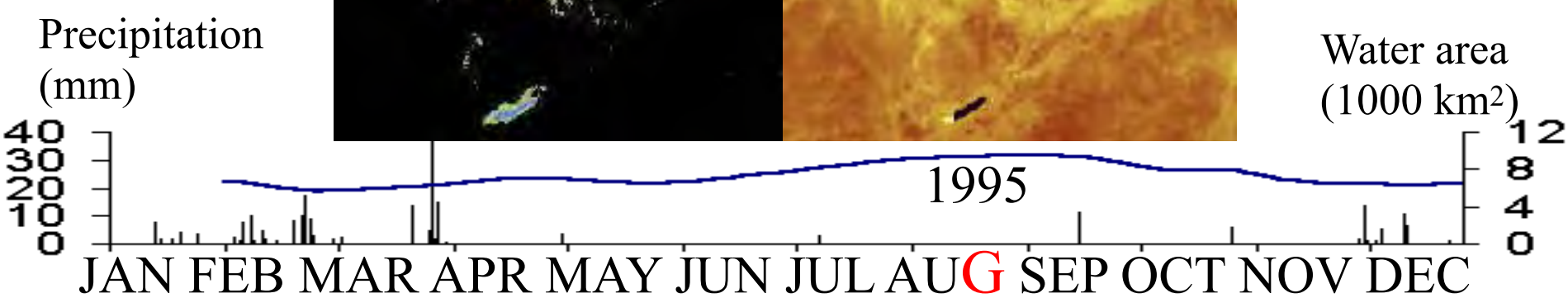




Okavango Delta, Botswana

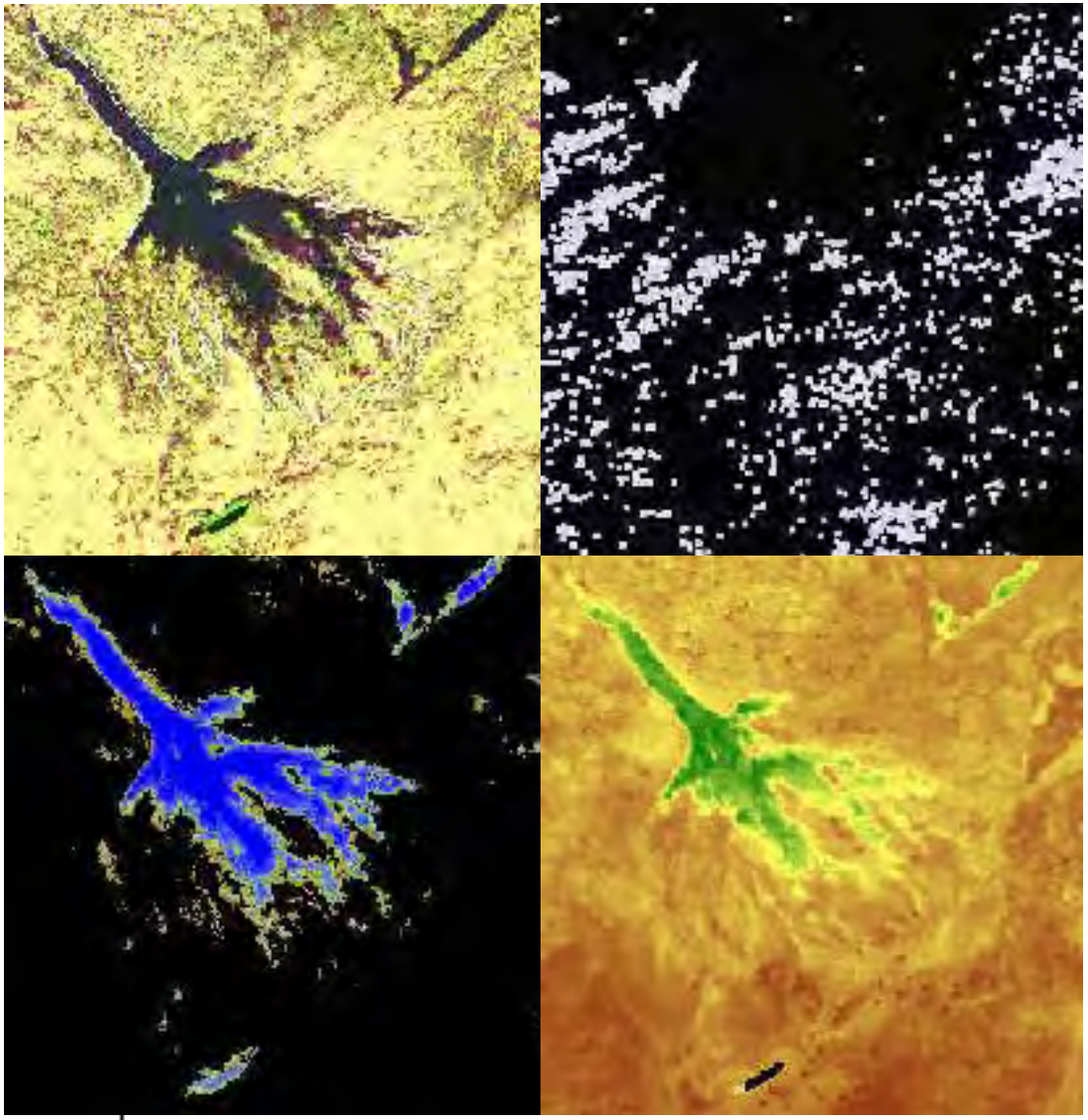
NOAA-AVHRR Images

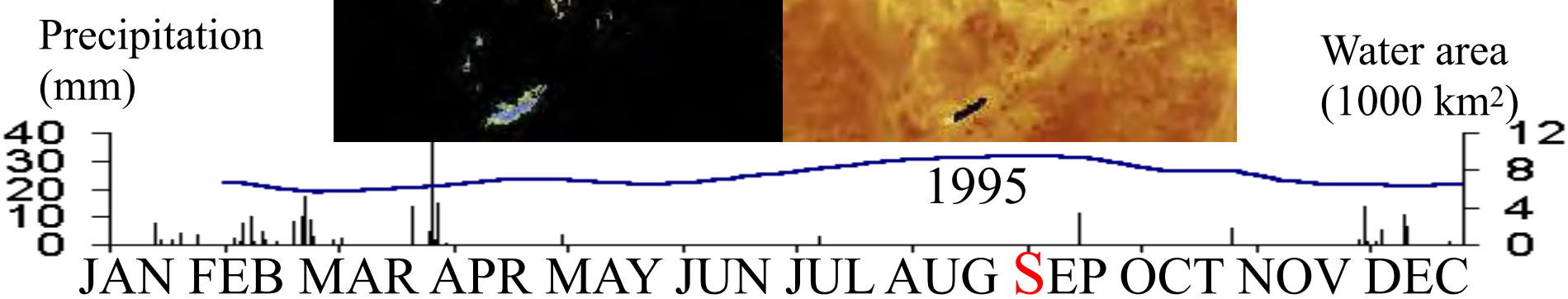




Okavango Delta, Botswana

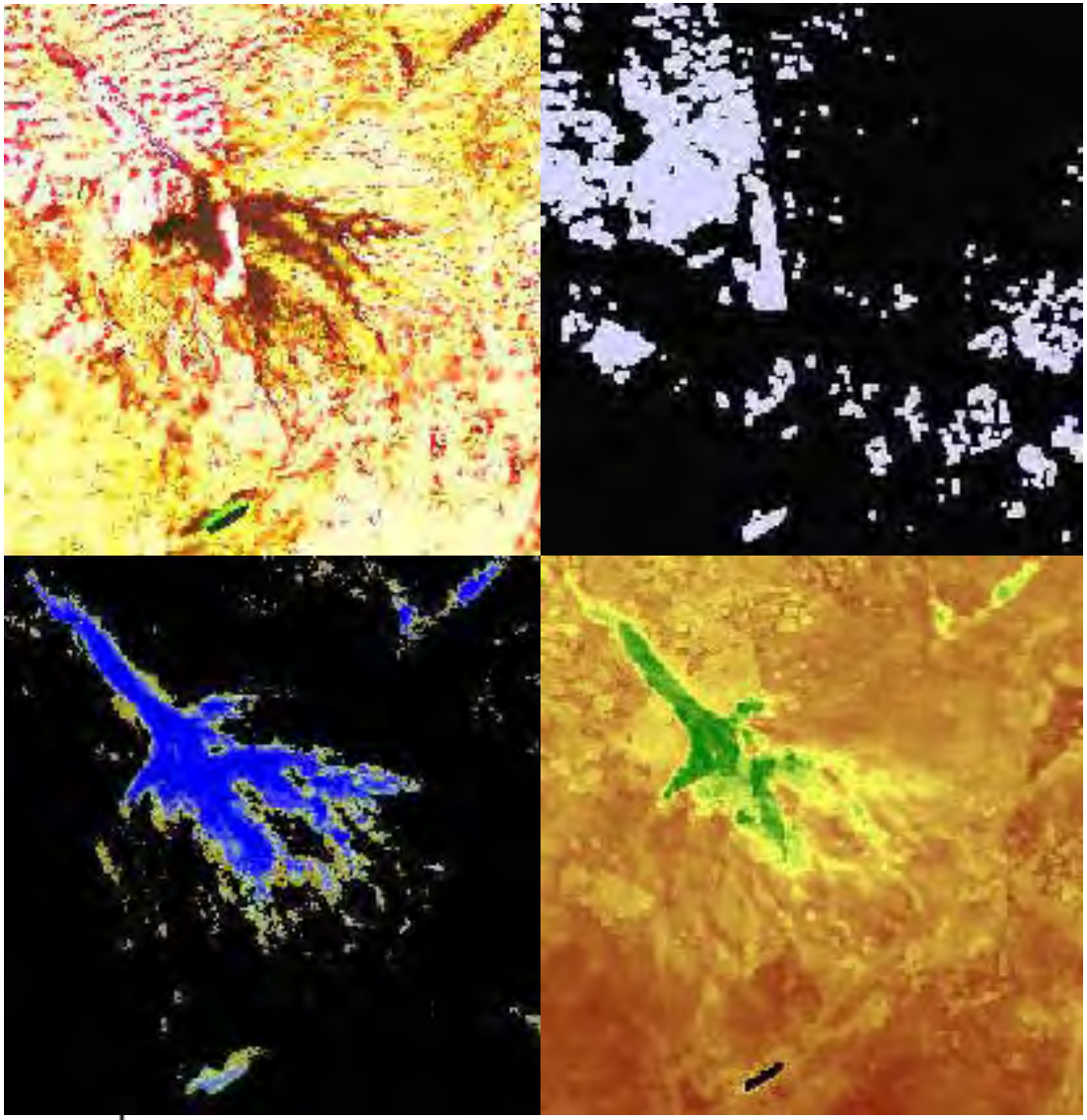
NOAA-AVHRR Images

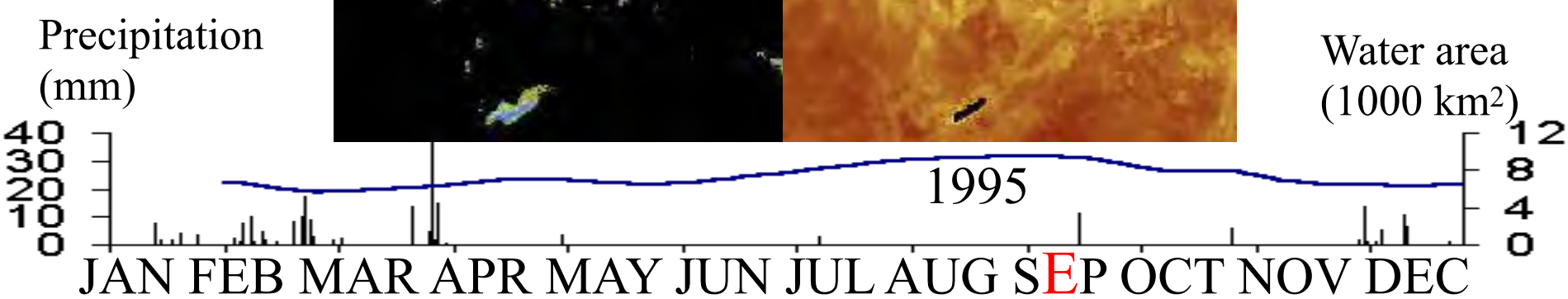




Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

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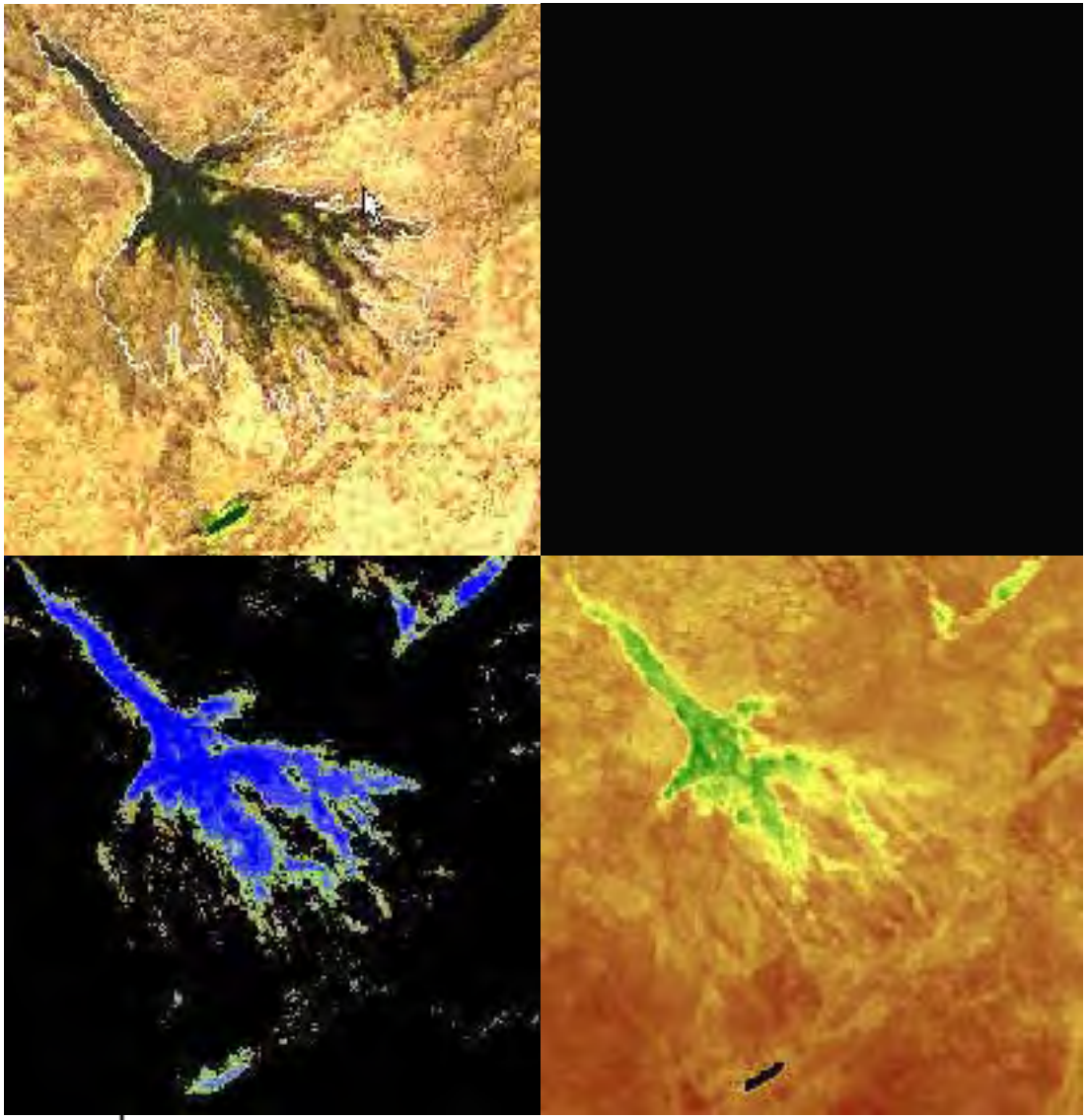


True colours

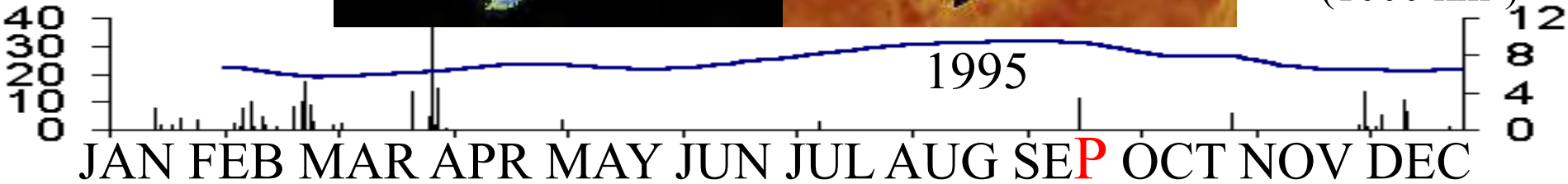
Clouds

Water

NDVI

N

100 Km



Okavango Delta, Botswana

NOAA-AVHRR Images

True colours

Clouds

Water

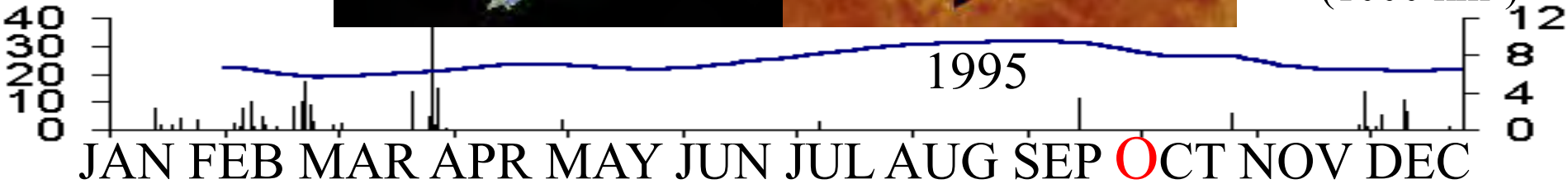
NDVI

N

100 Km

Precipitation (mm)

Water area (1000 km²)



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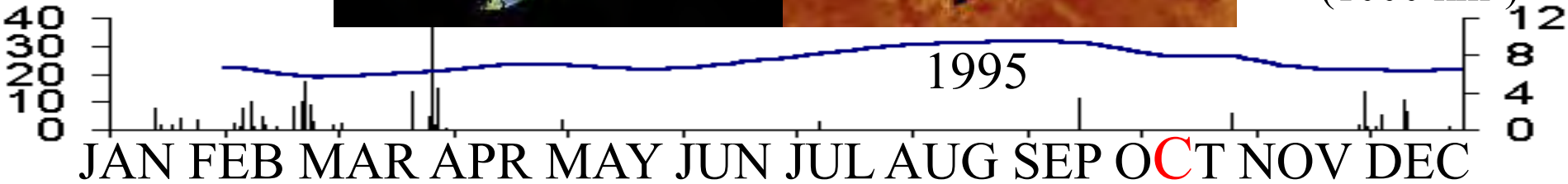
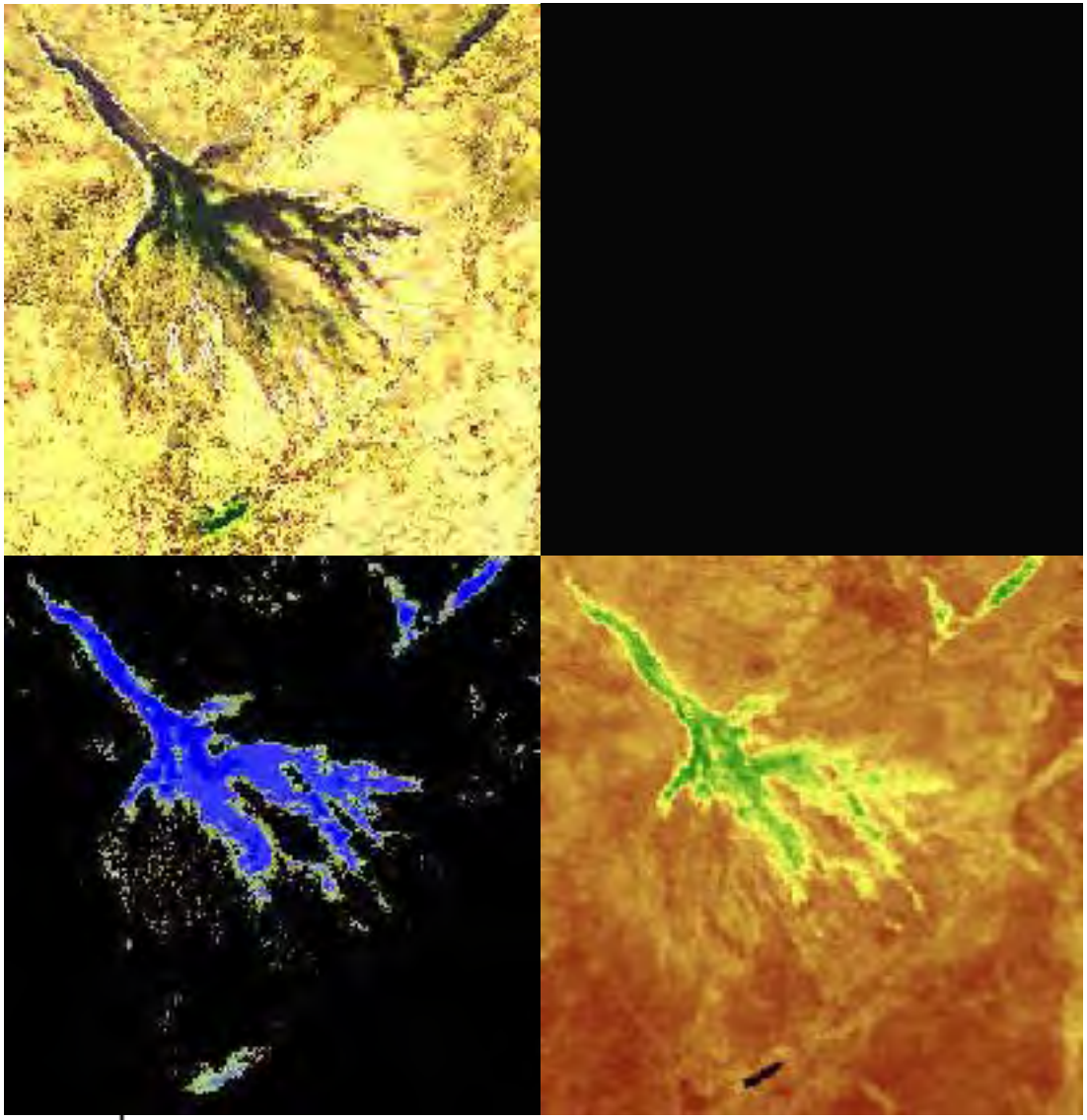
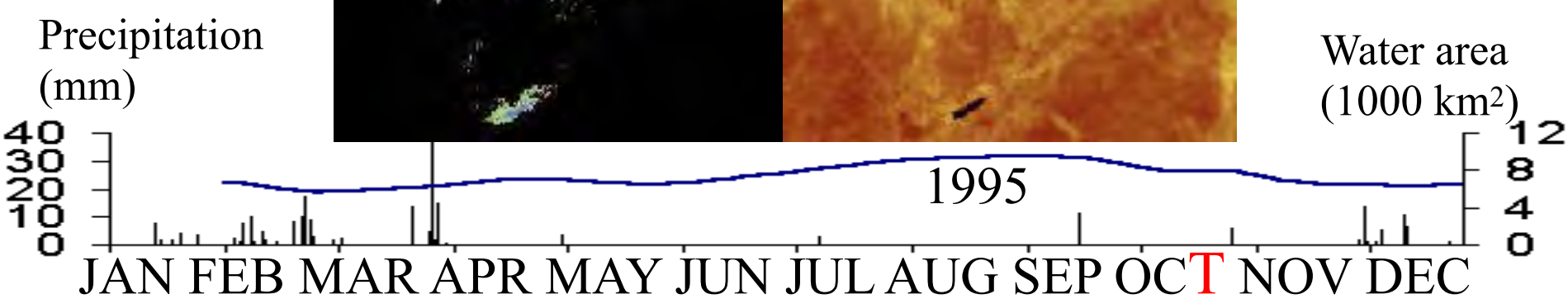


Okavango Delta, Botswana

NOAA-AVHRR Images





Okavango Delta, Botswana

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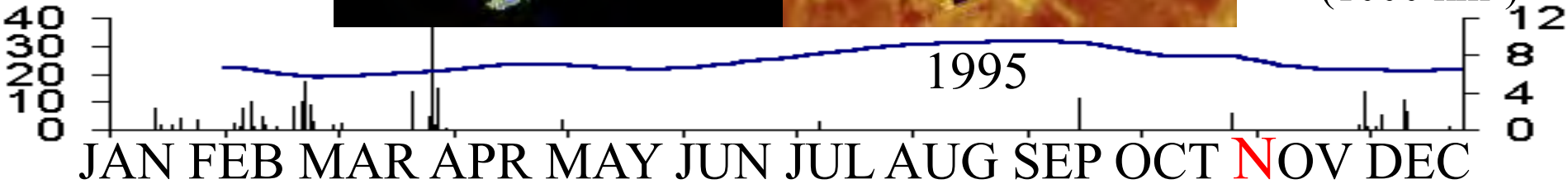
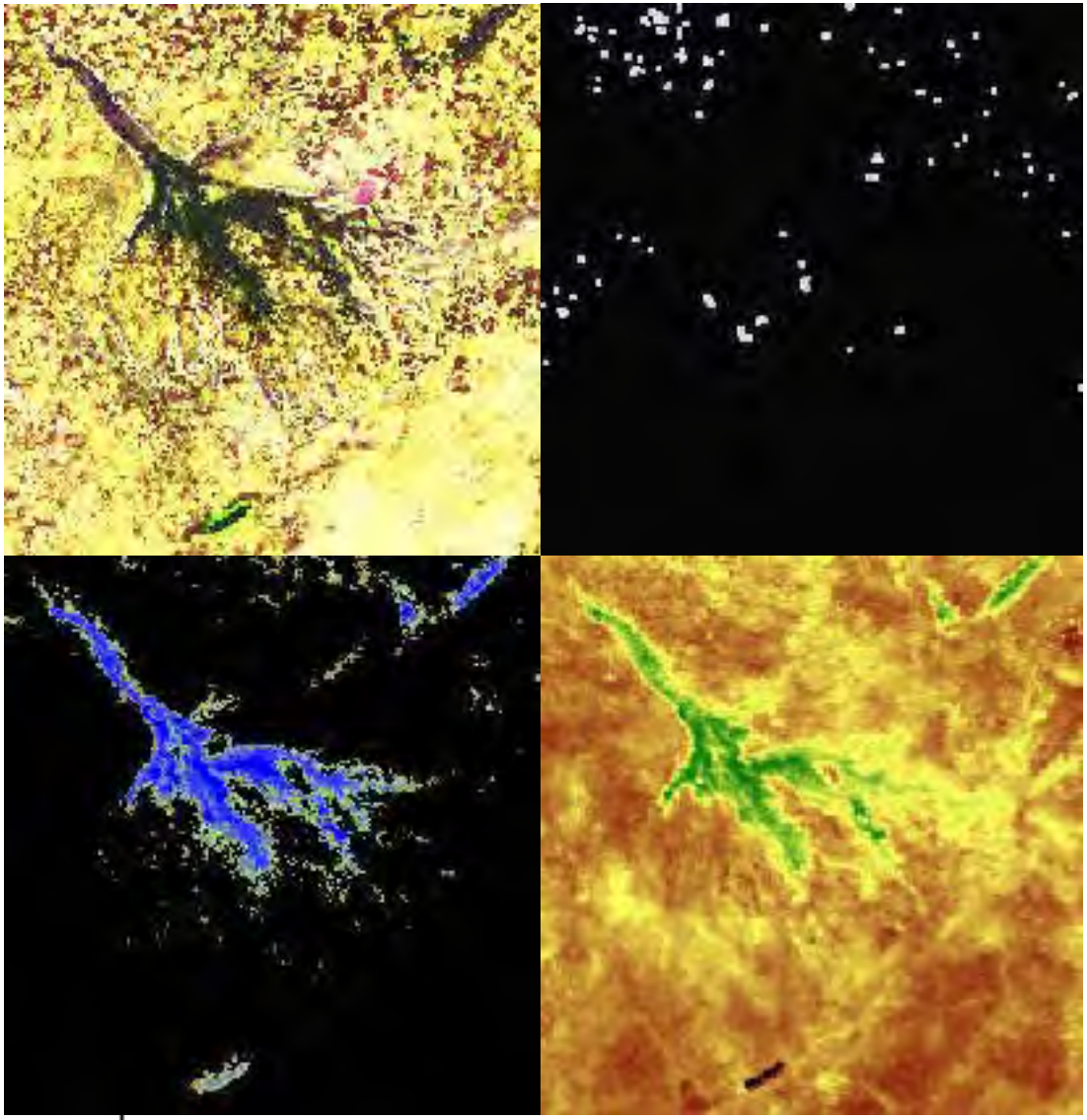
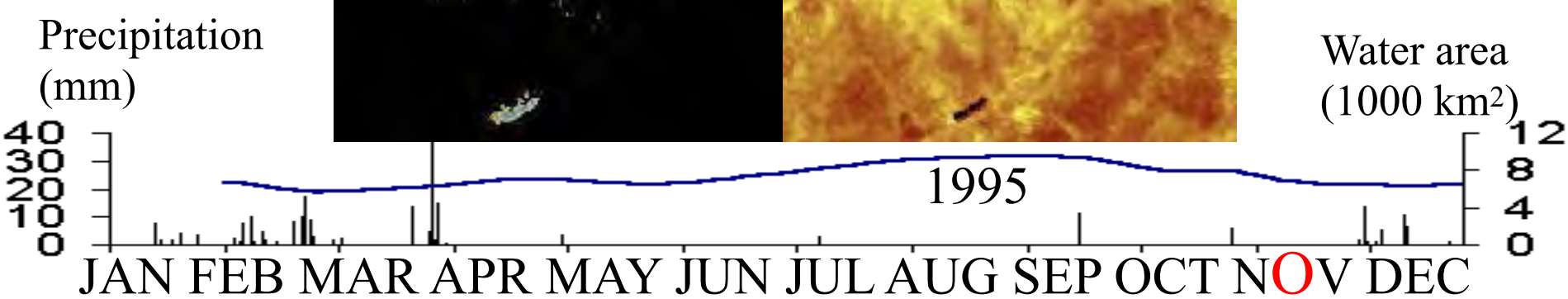


Okavango Delta, Botswana

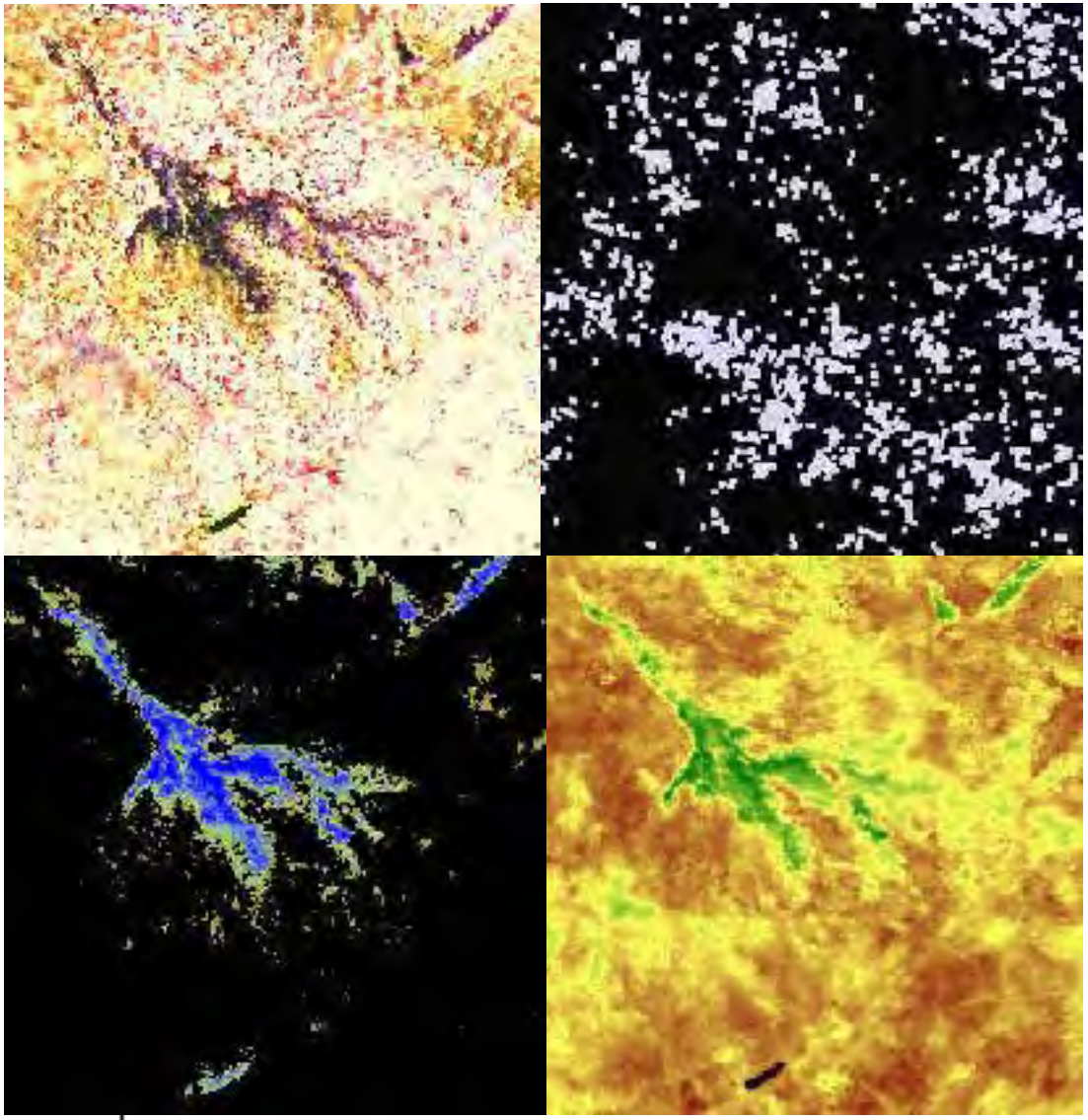
NOAA-AVHRR Images

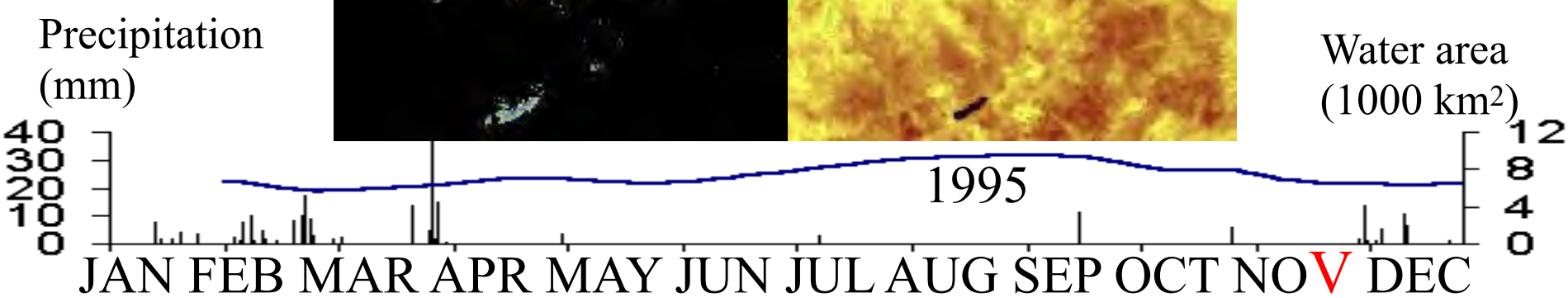




Okavango Delta, Botswana

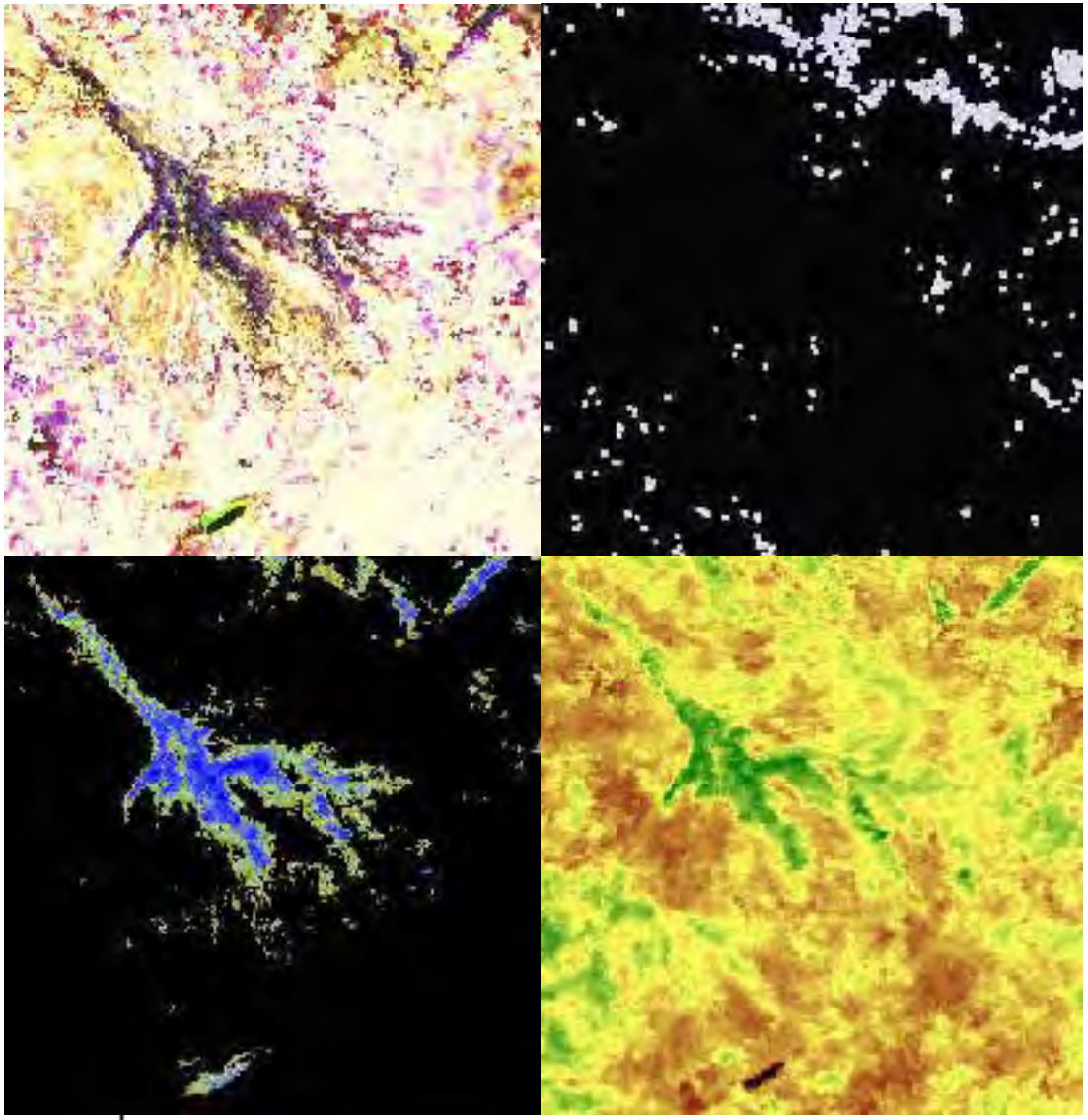
NOAA-AVHRR Images

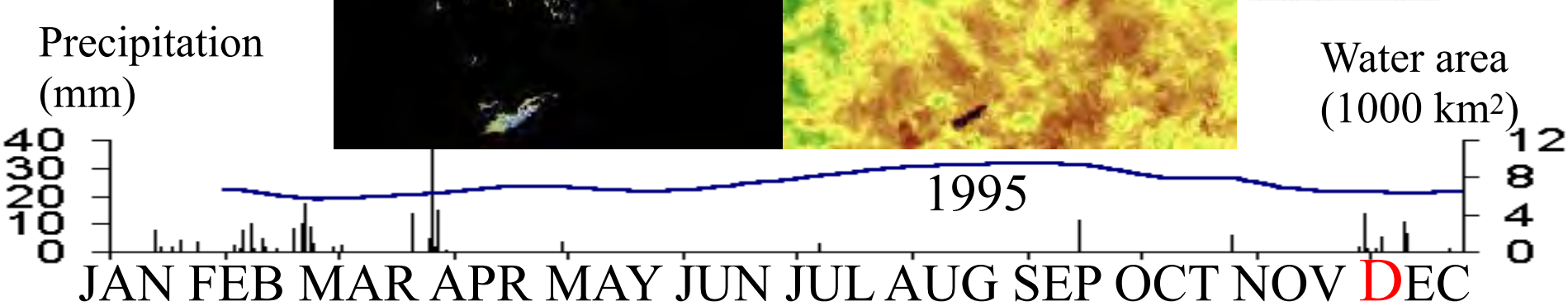




Okavango Delta, Botswana

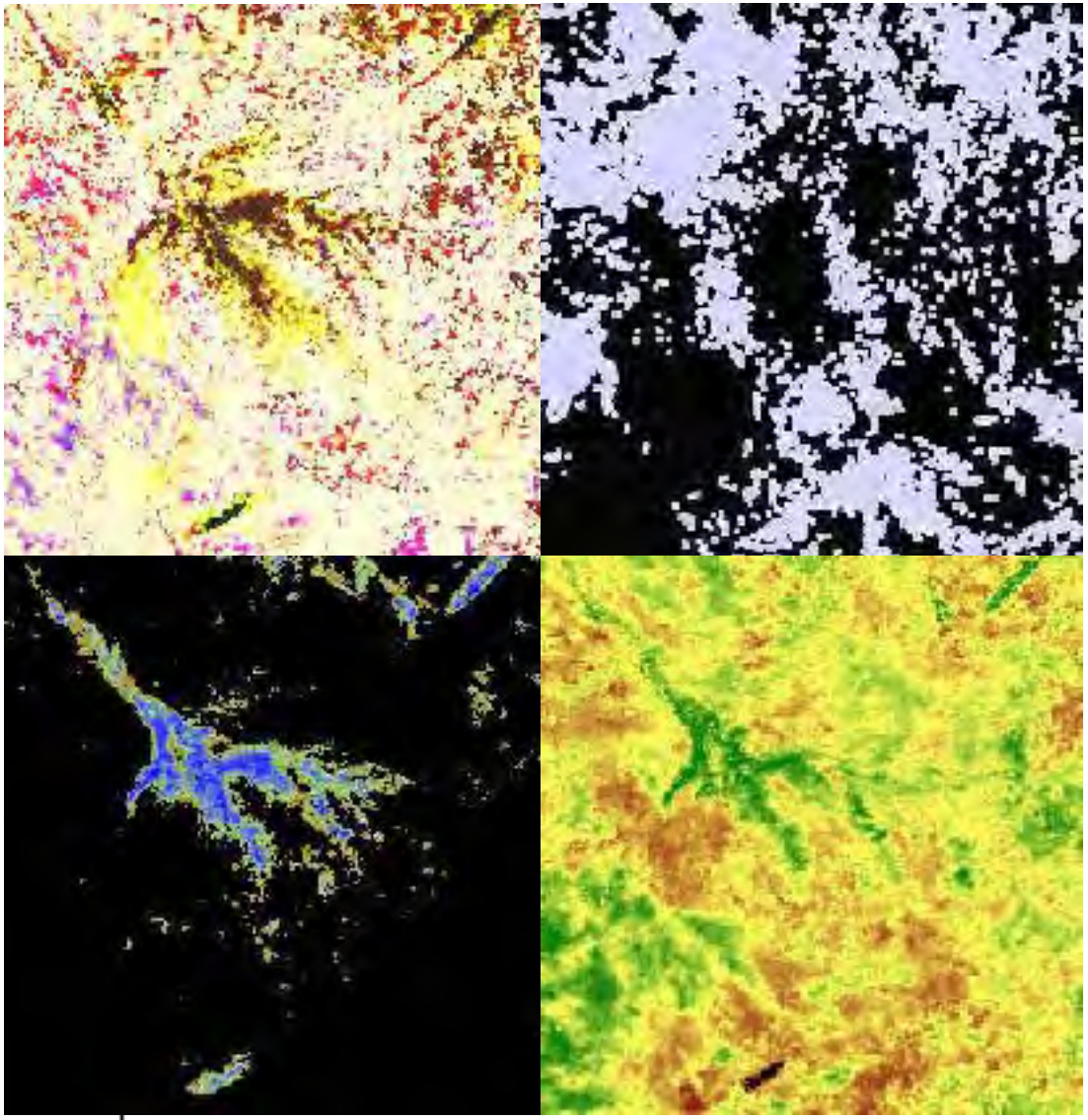
NOAA-AVHRR Images

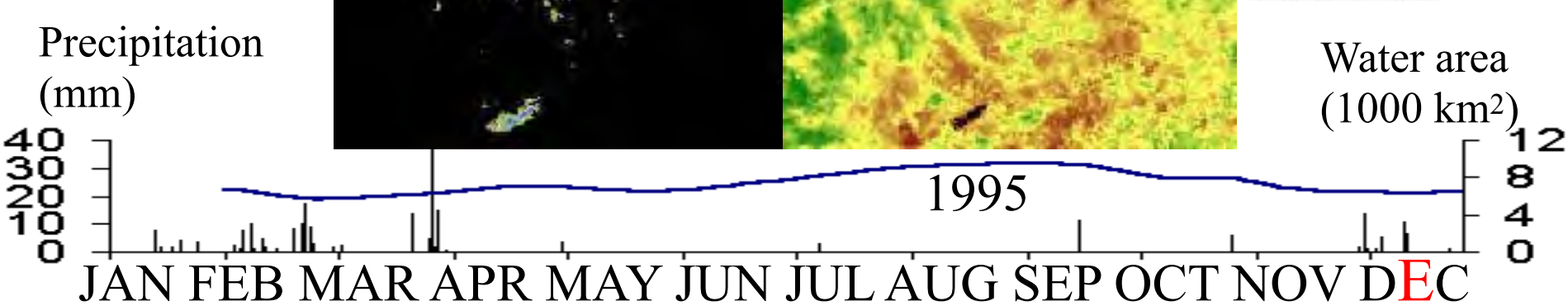




Okavango Delta, Botswana

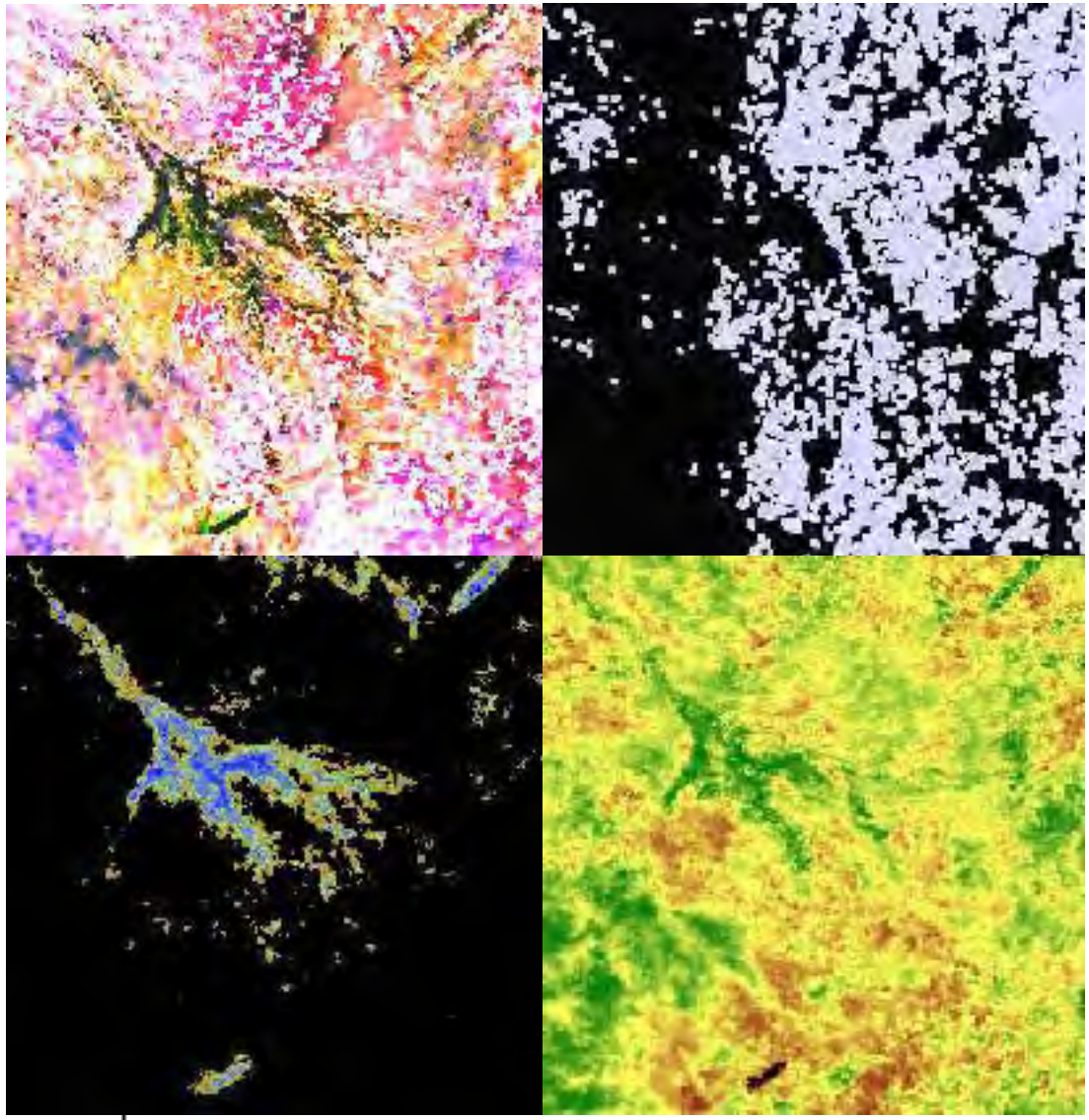
NOAA-AVHRR Images

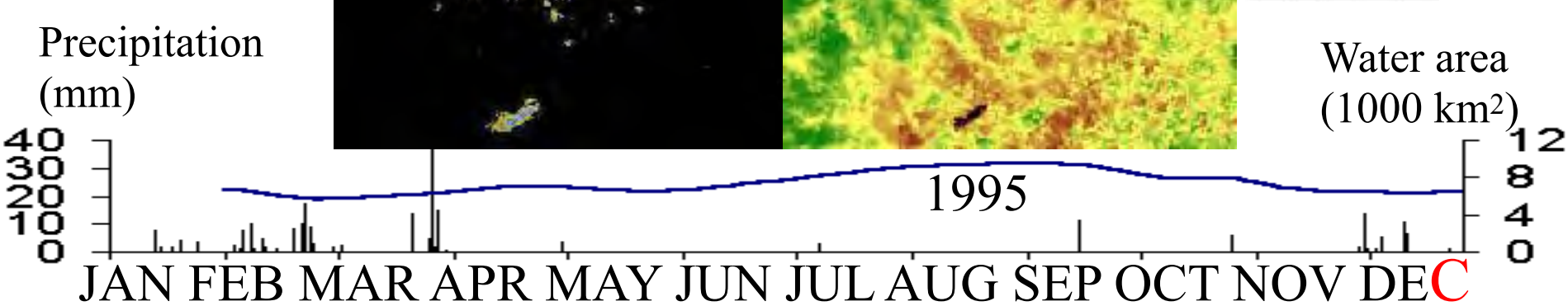




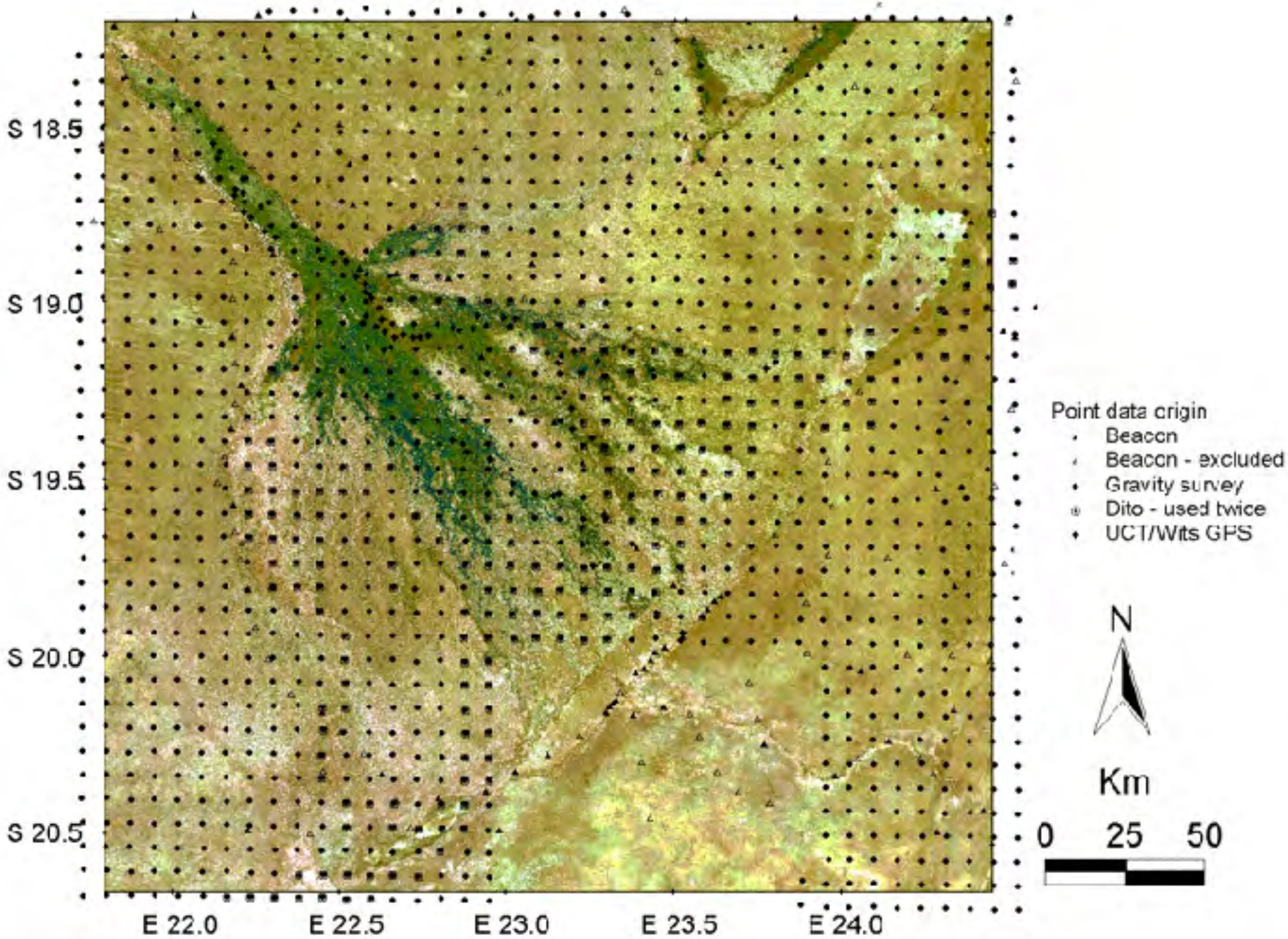
Okavango Delta, Botswana

NOAA-AVHRR Images

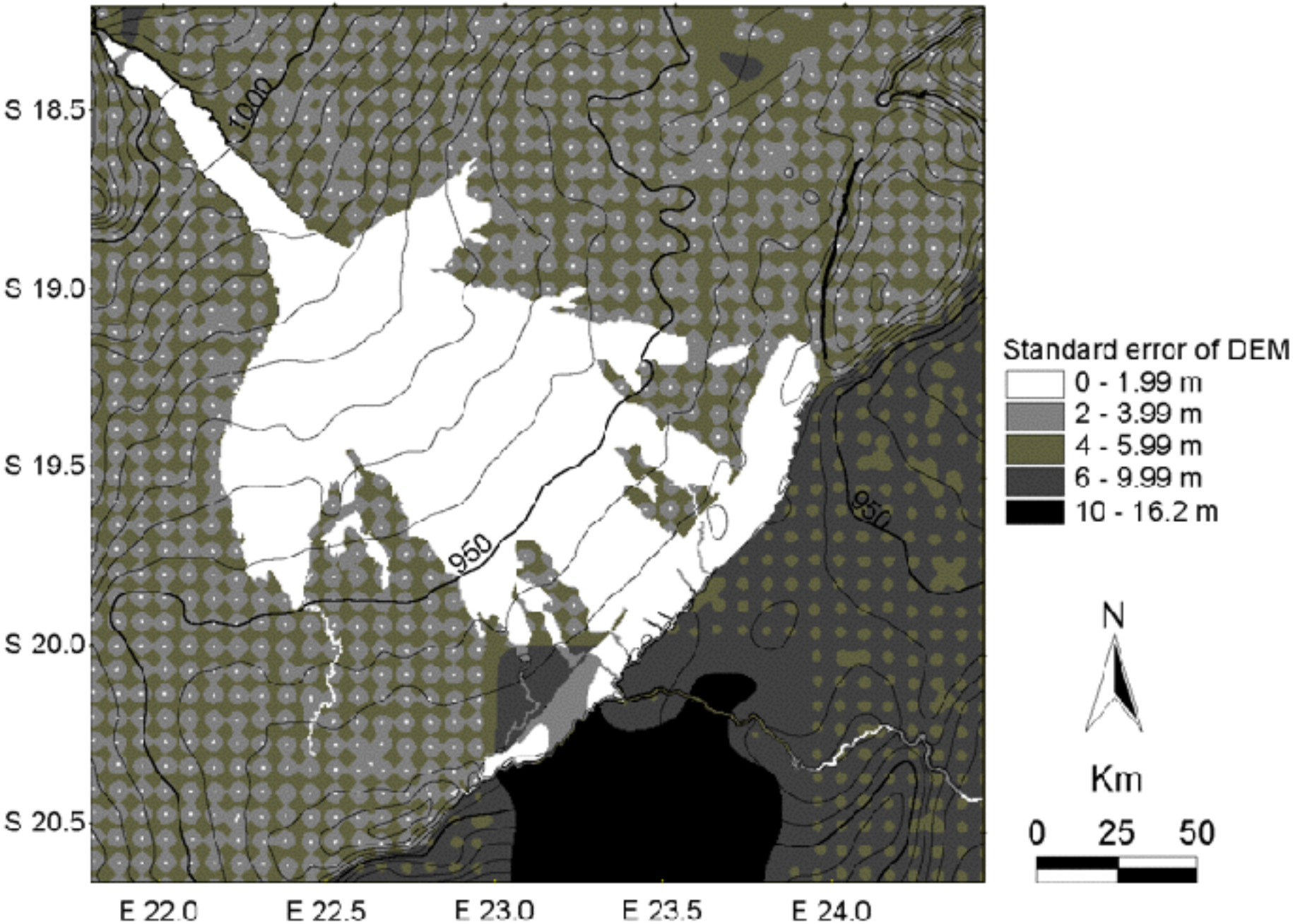




Surveyed elevation points in the Okavango Delta, Botswana

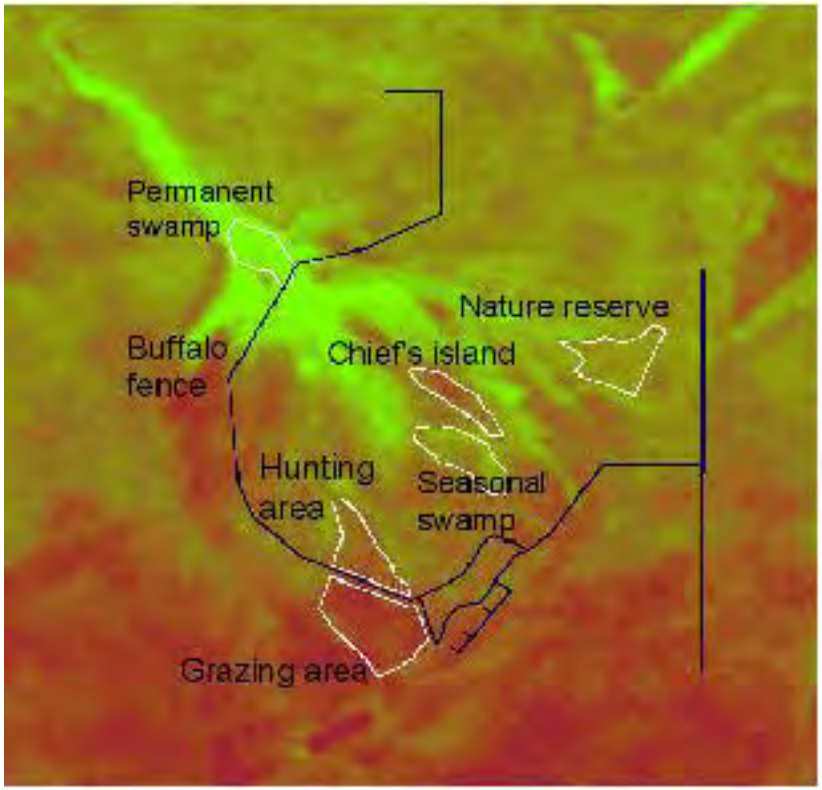


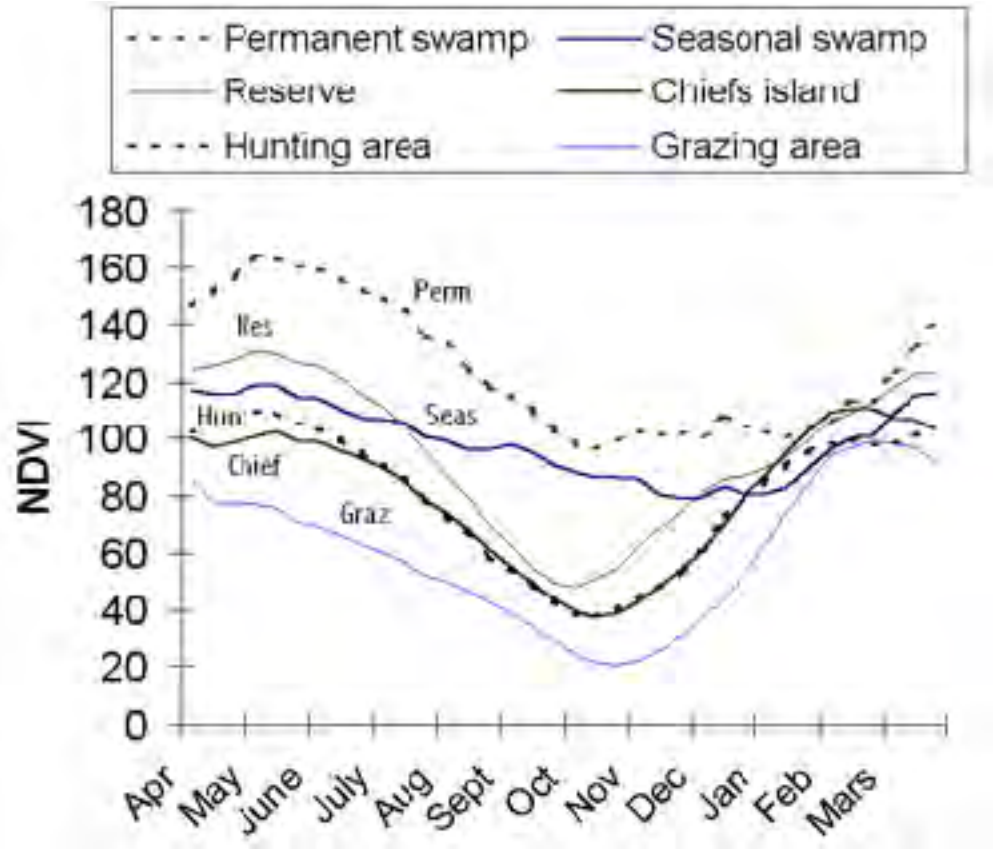
Regional division of geostatistical interpolation and standard error



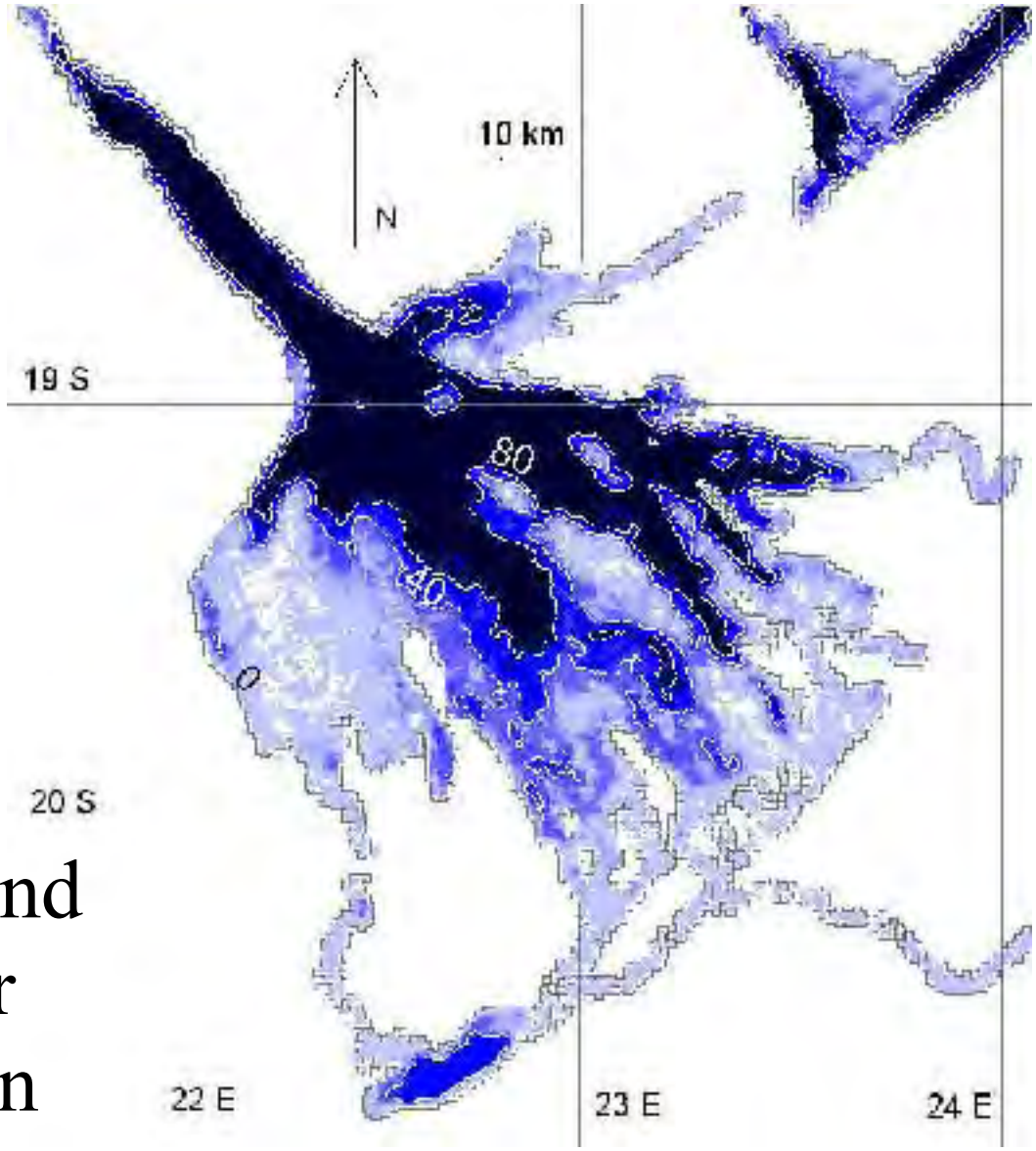
Results

Spatial and temporal variaton of NDVI

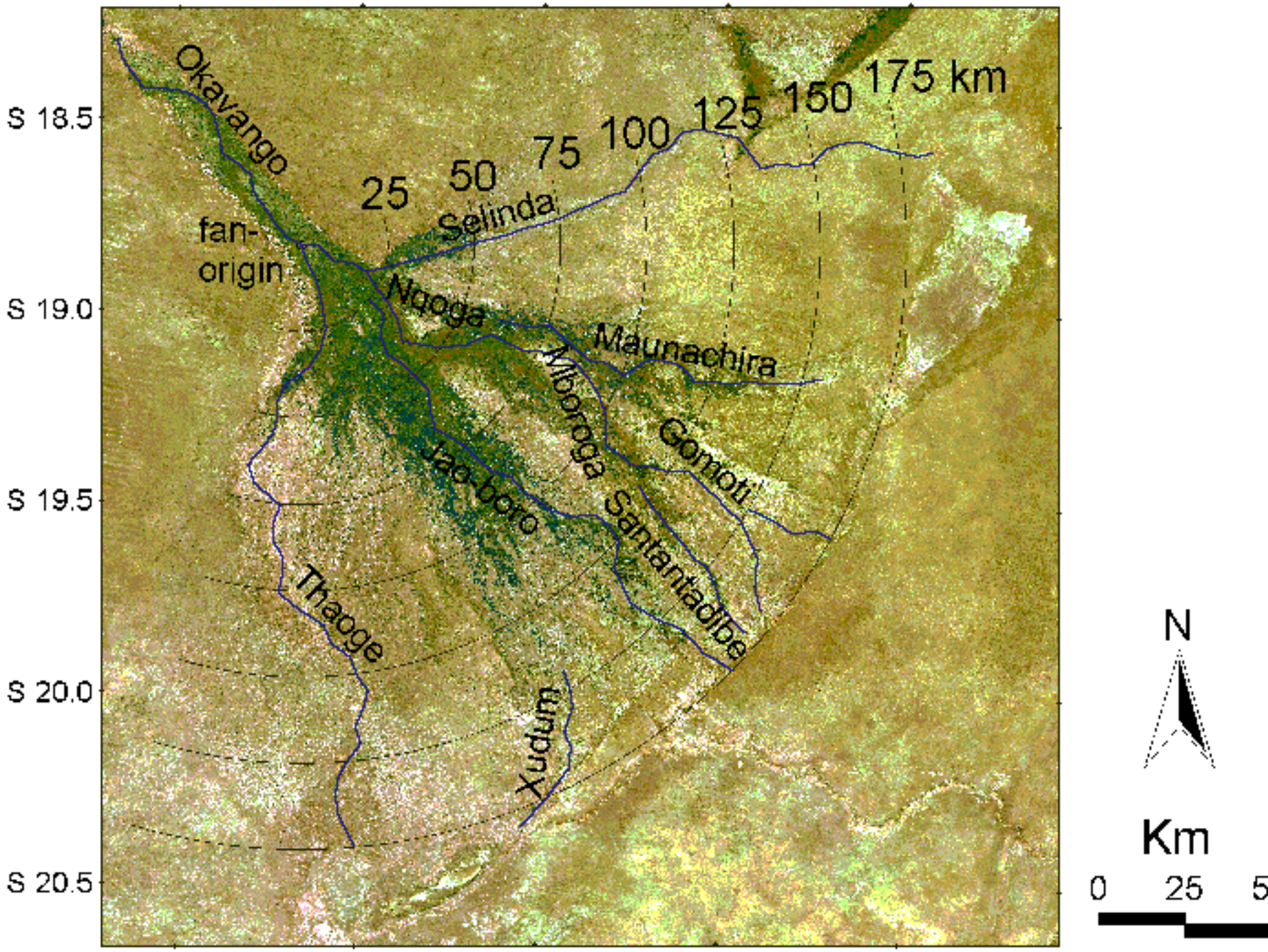




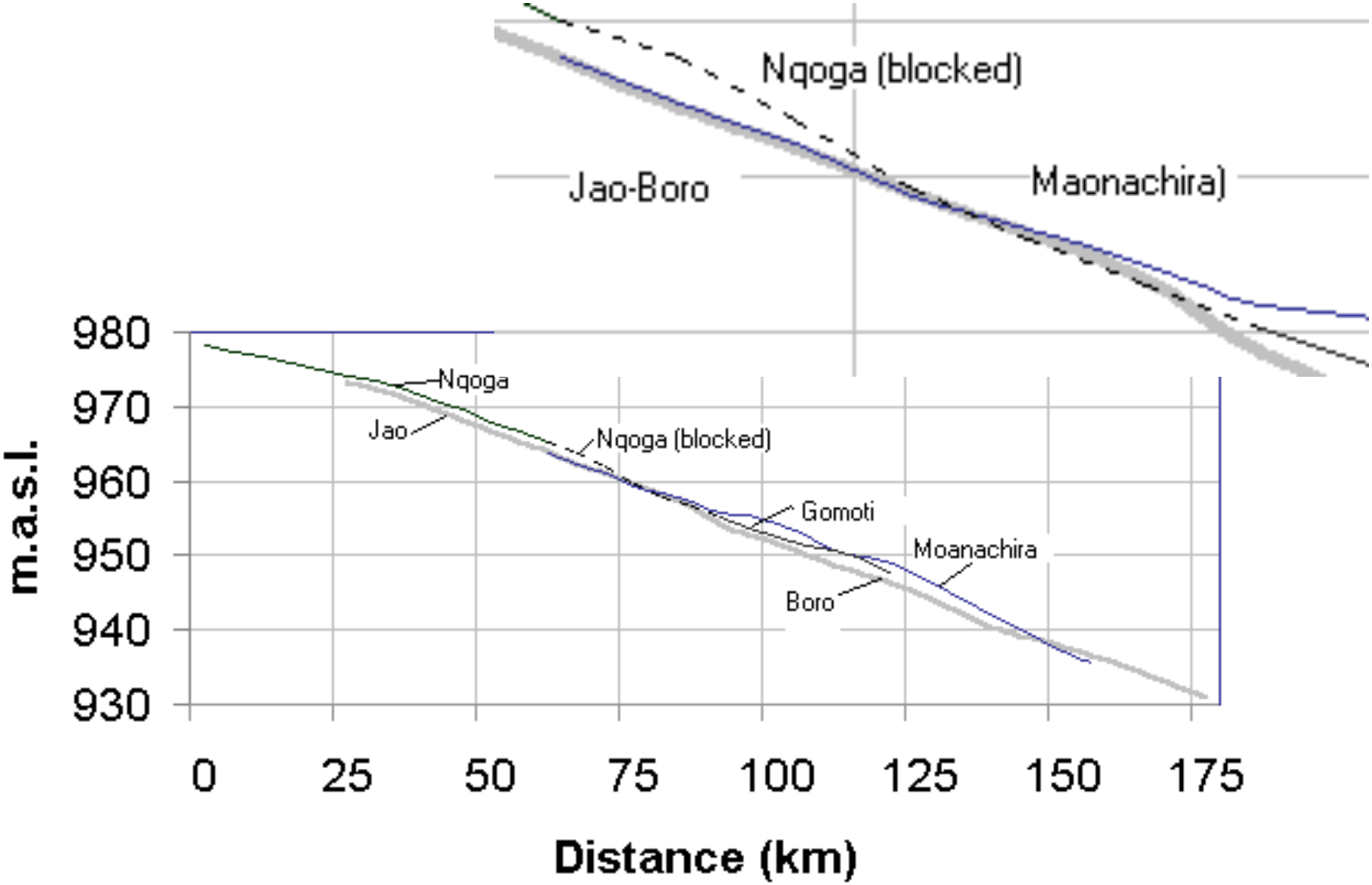
Percent of time with water cover



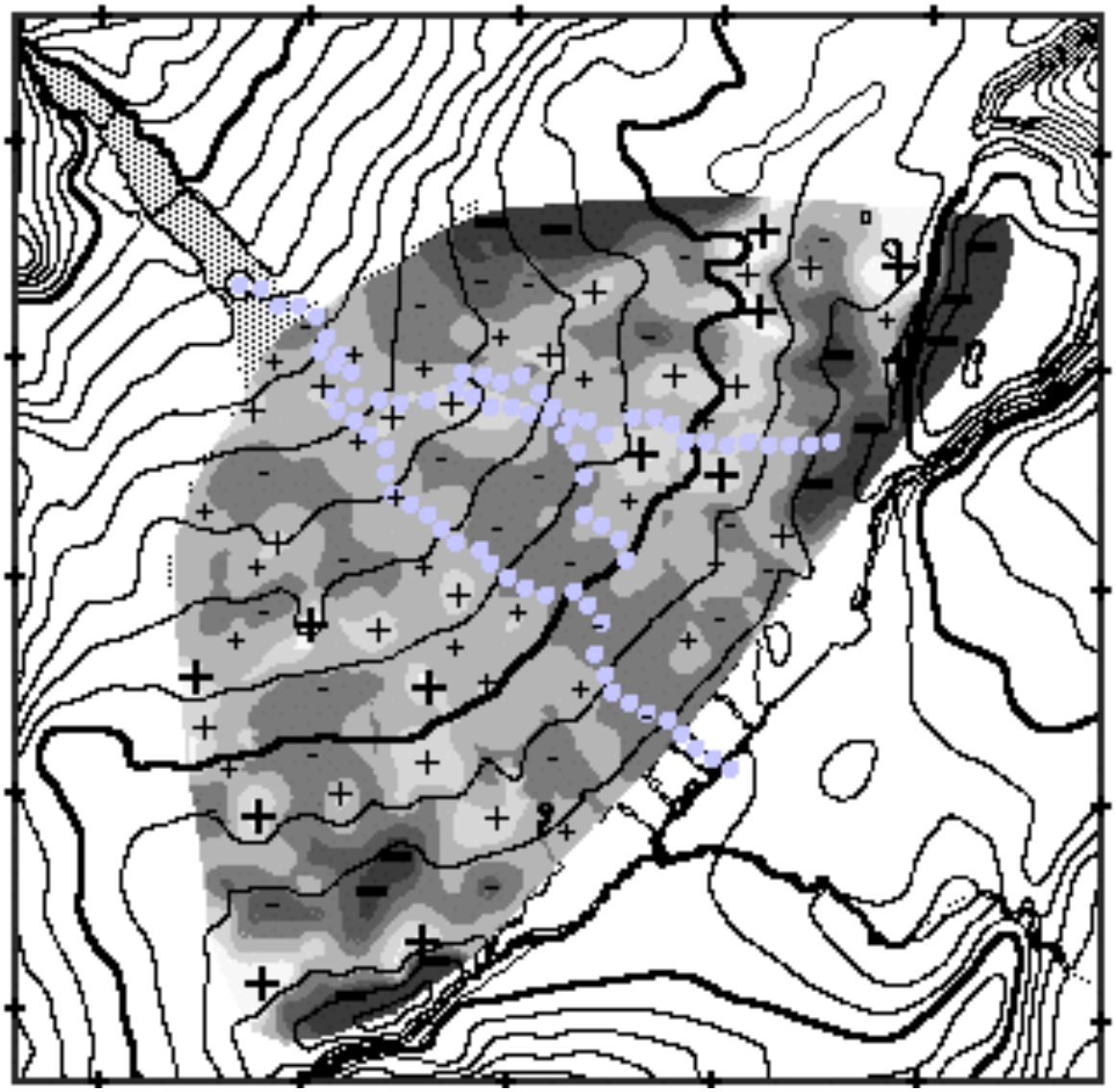
Isolines for 0, 40 and 80 % time of water coverage are shown


S 18.5
S 19.0
S 19.5
S 20.0
S 20.5
Okavango
fan-
origin
25
50
75
100
125
150
175 km
Selinda
Nqoga
Maunachira
Mboroga
Gomoti
Jao-boro
Santantadibe
Thaoge
Xudum
N
Km
0
25
5

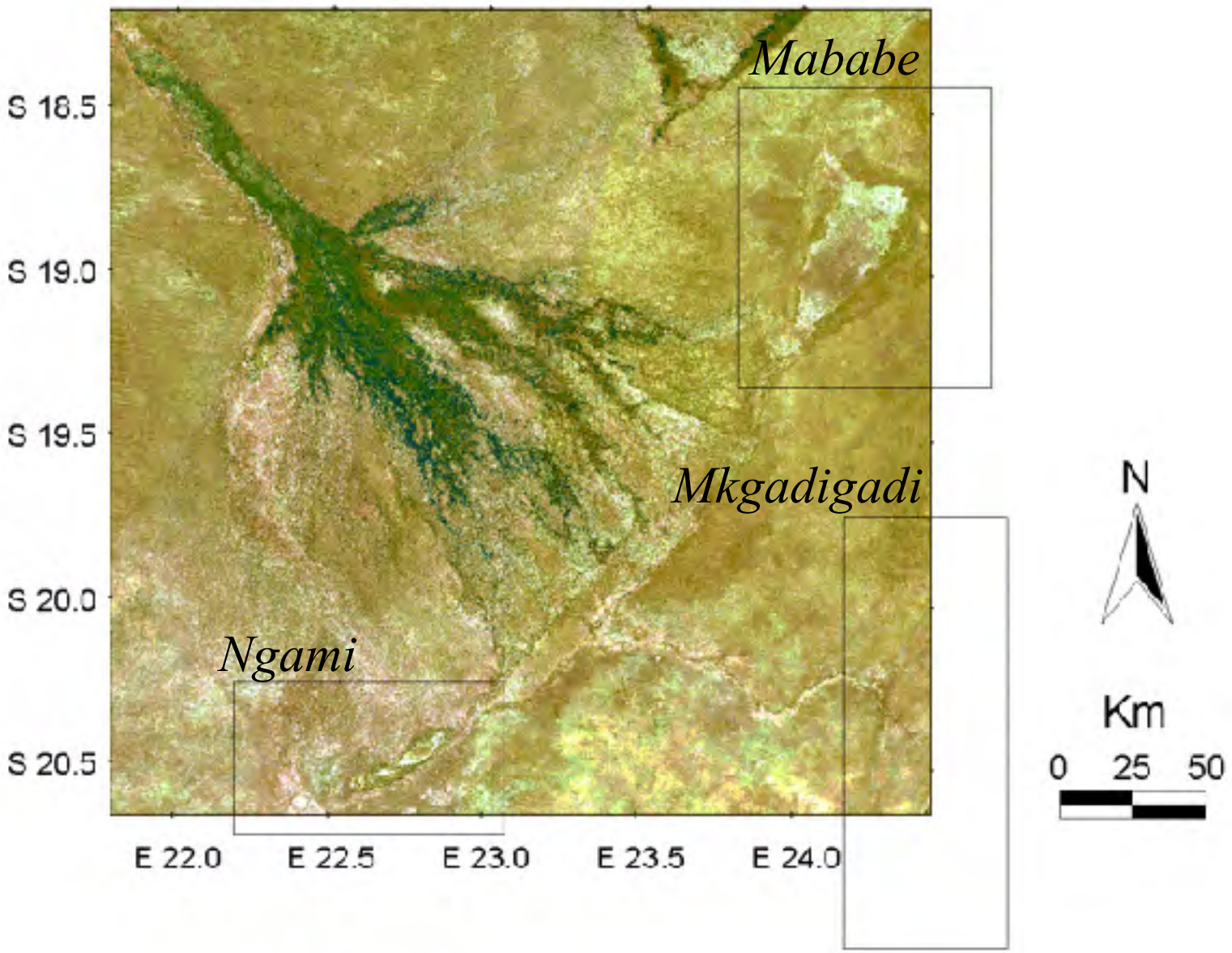
Elevation profiles along channels

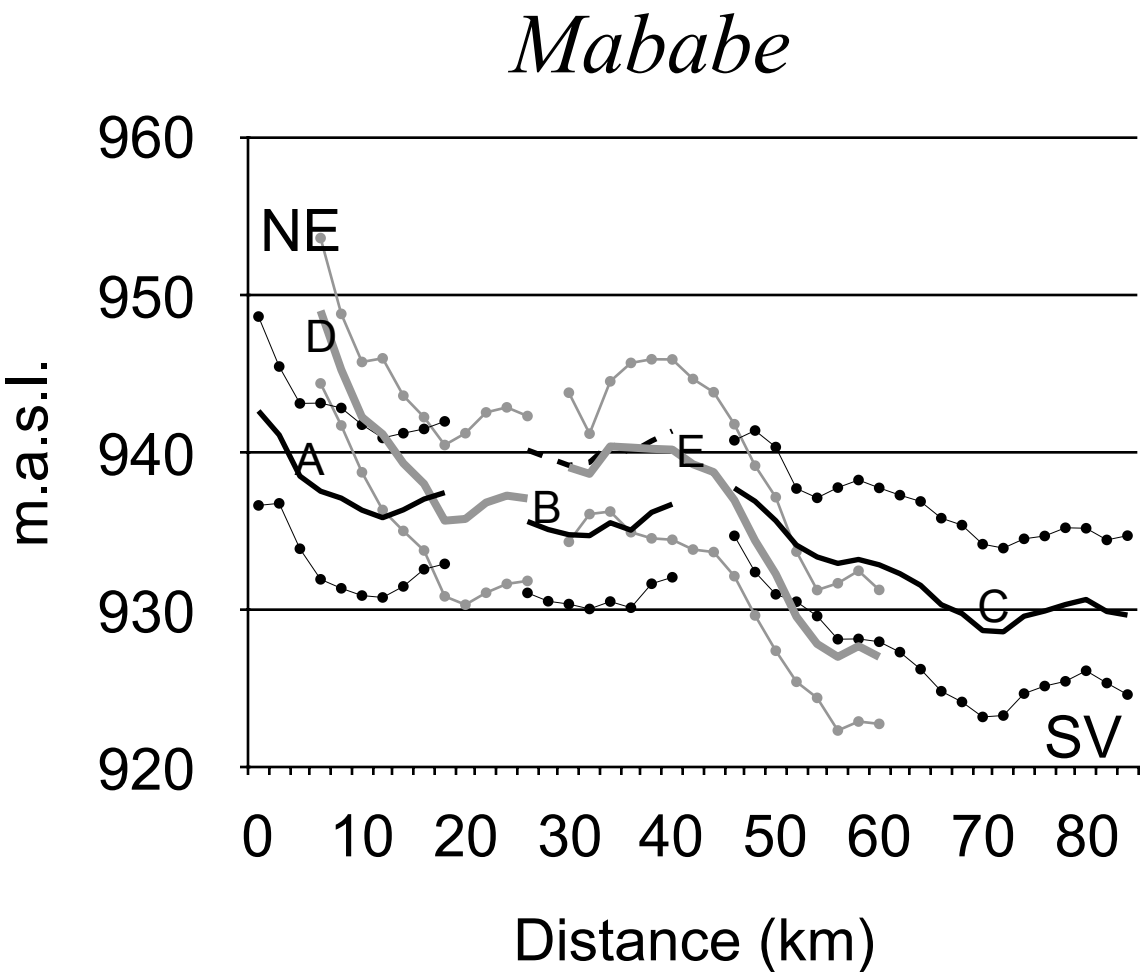


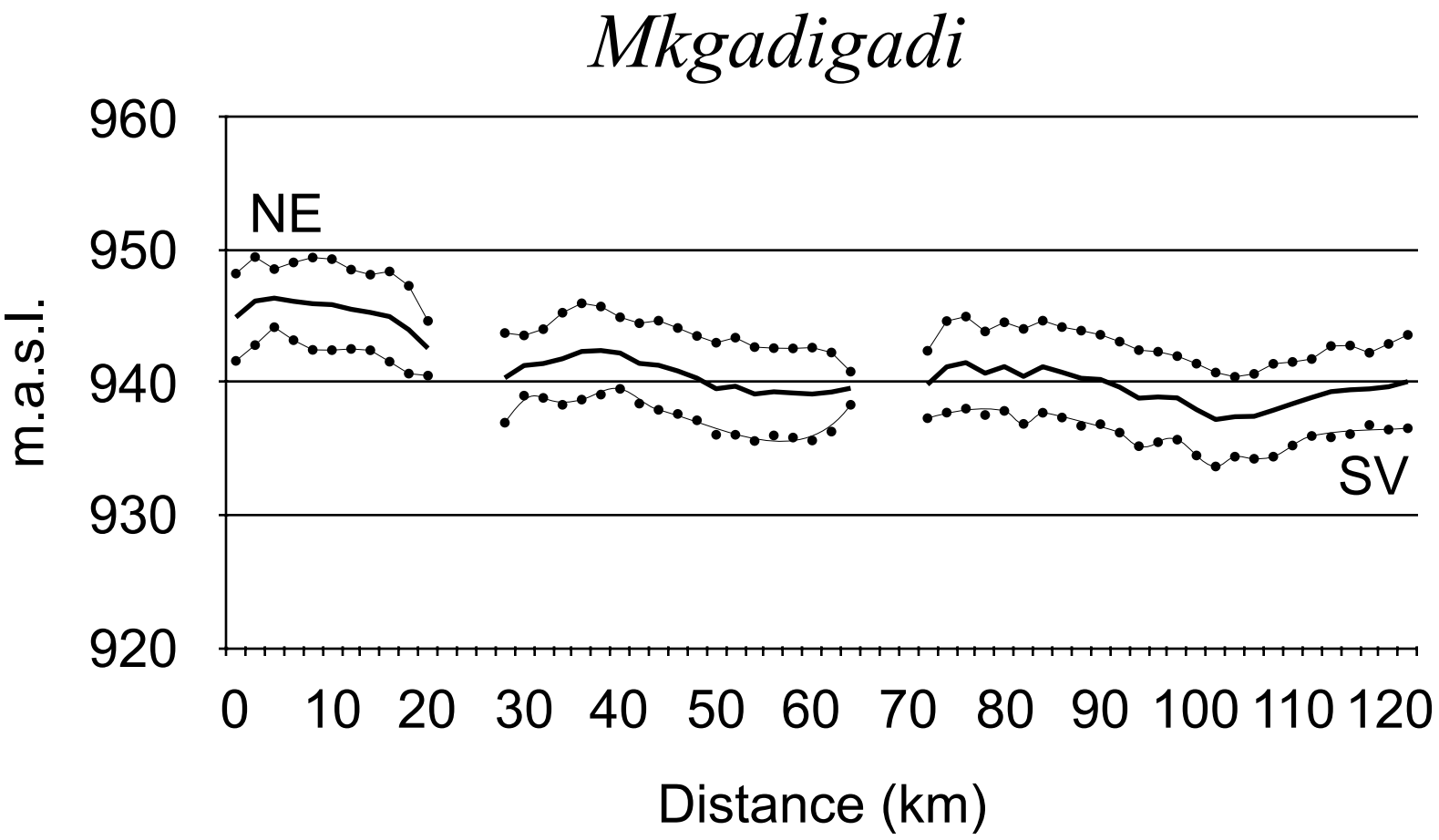
Residual elevation



Paleolakes with shores identifiable from Landsat TM data




Mababe
960
950
940
930
920
m.a.s.l.
NE
D
A
B
E
C
SV
0
10
20
30
40
50
60
70
80
Distance (km)


Mkgadigadi
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950
940
930
920
m.a.s.l.
NE
SV
0
10
20
30
40
50
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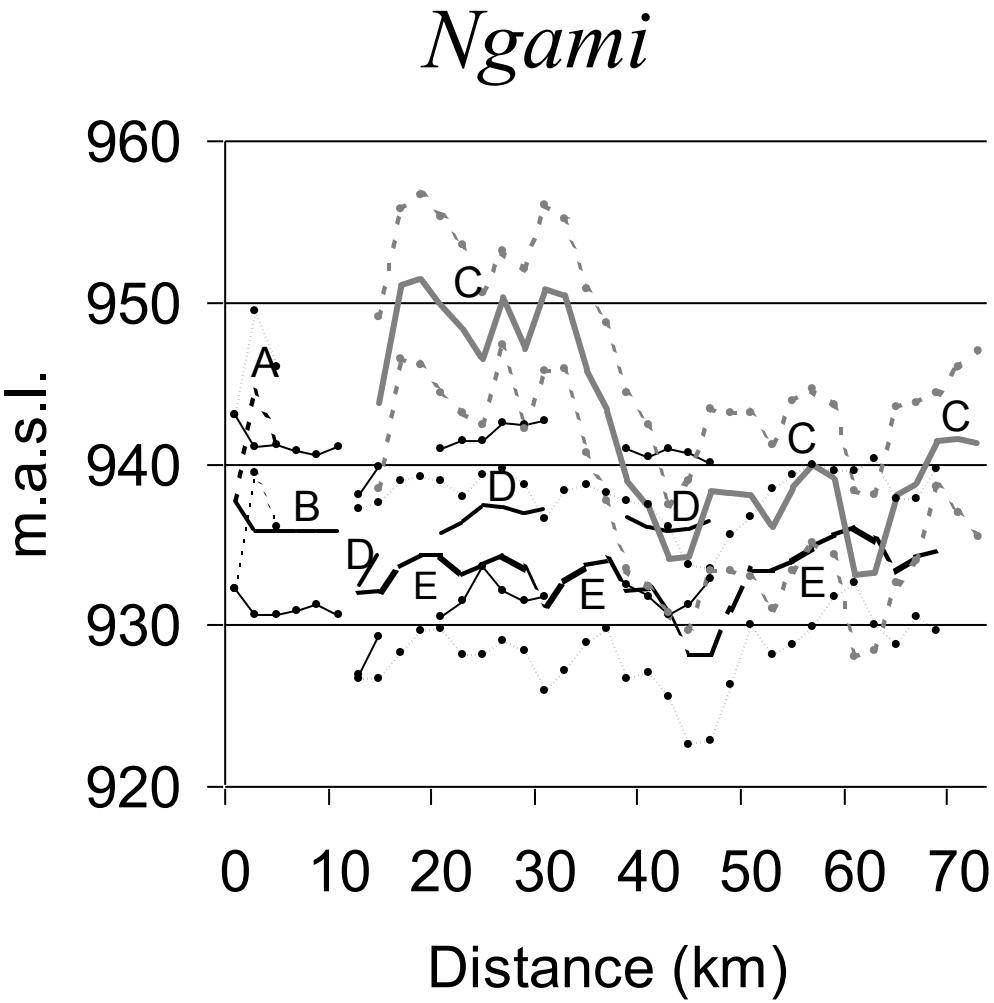
100
110
120
Distance (km)


Ngami
960
950
940
930
920
m.a.s.l.
0
10
20
30
40
50
60
70
Distance (km)
A
B
C
D
E

Summary of results:

The study confirms the anecdotal knowlegde about the extension and area of the delta, and adds quantitative estimates

The major area for the seasonal flood is today towards southeast

The vegetational cycle is differing over the physiographic regions, with clear human fingerprint on grazing areas

Interannual variations are large both regarding floods and vegetation

The object oriented method for classification of island features works, grund truth data collected in coordiantion with SAFARI 2000 will beused for evaluating the classification

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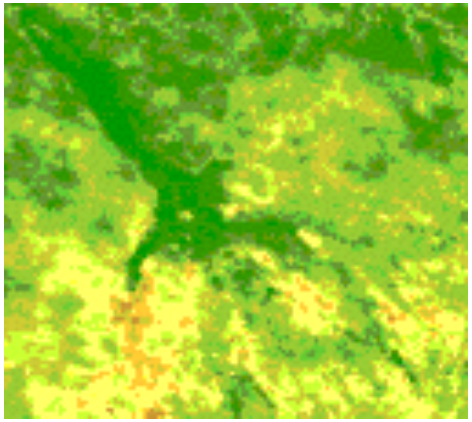

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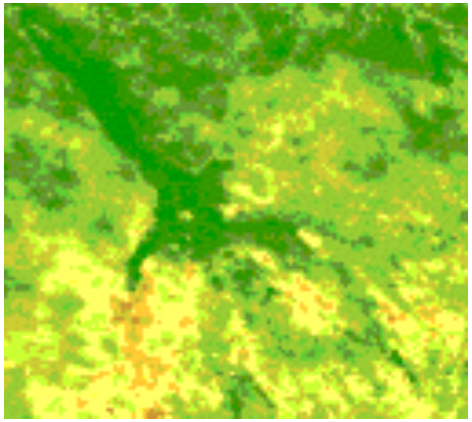

Summary of results:

The study confirms the anecdotal knowlegde about the extension and area of the delta, and adds quantitative estimates

The major area for the seasonal flood is today towards southeast

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Summary of results:

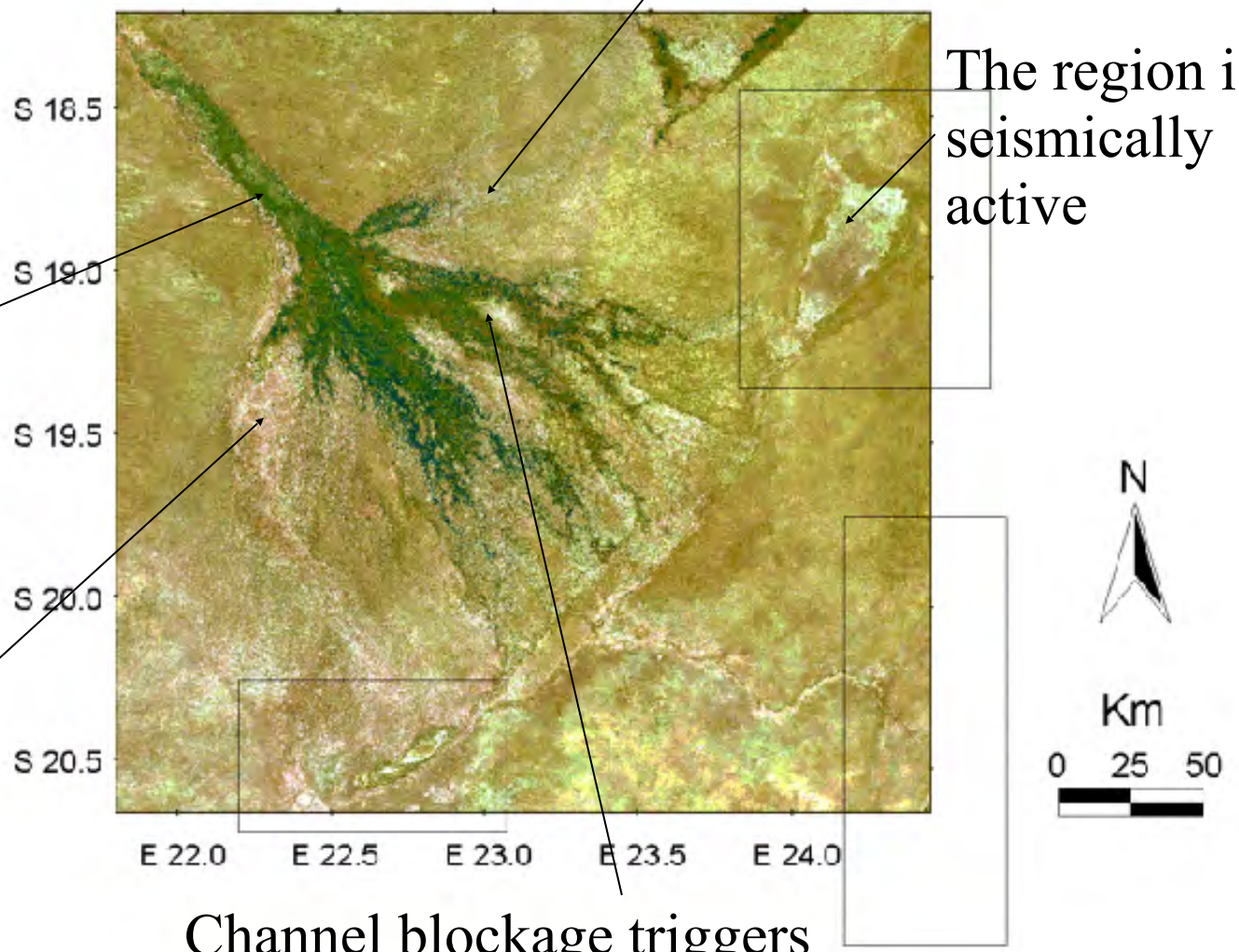
Eventually the Delta will drain to Zambezi

The region is seismically active

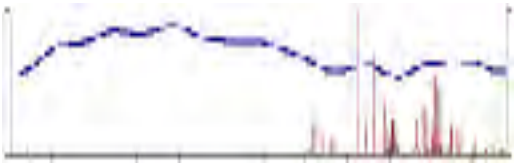
The Panhandle is a graben

Sedimentation reshapes the delta continously

Channel blockage triggers channel death and birth



Conclusions



Conclusions:

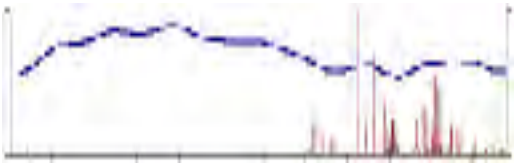
tautological

The complexity of the delta calls for a hierarchical perspective nesting scales and seeking symmetries in space and time

Remotely sensed data combined with in situ data at key nodes best or even only(?) monitoring solution

lack of sufficient *in situ* data hampers assessment of the accuracy

The lack of base line data prevents robust conclusions on the geophysiological integrity of the delta



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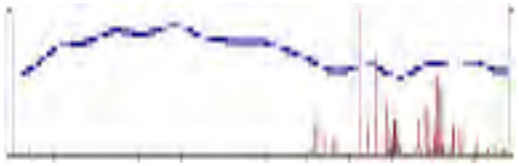

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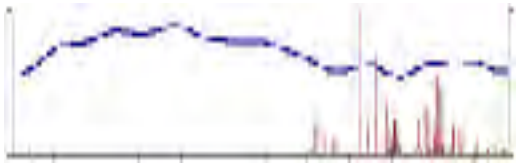

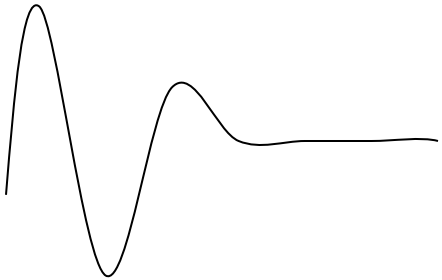

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NASA, ESA, USGS, SADC, FAO, WMO are you listening?

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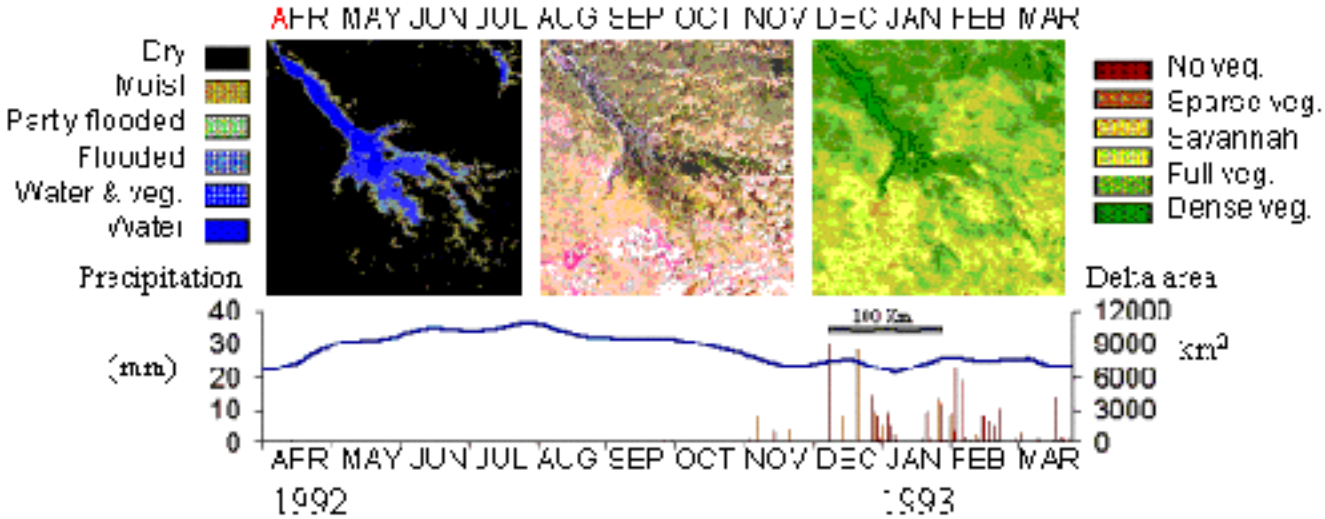
Thanks to the Swedish Royal Academy of Sciences, that kindly granted me a post-doc for this study



Animationer finns på nätet:

www.geoinformatik.geo.uu.se/forskning

(English translation in the pipe line)