

# Portraying the Geophysiology of the Okavango Delta, Botswana

Thomas Gumbrecht,

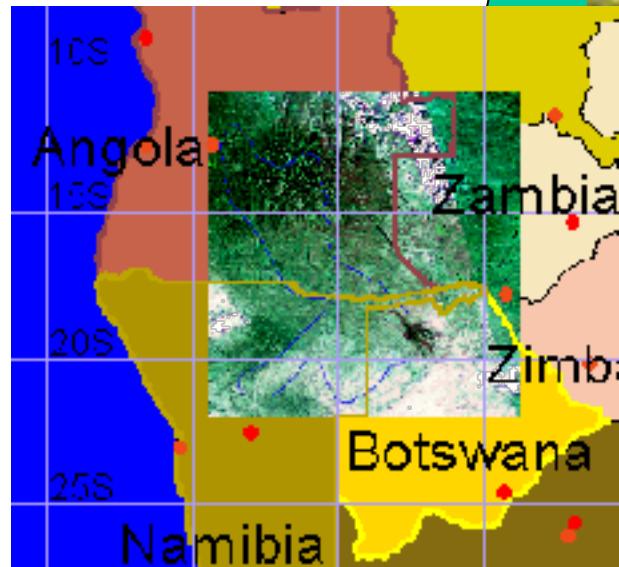
Jenny McCarthy,

Terence McCarthy

University of the Witwatersrand, South Africa

# Three "nested" hierarchical scales for portraying the Okavango Delta

Constraining scale



The Catchment

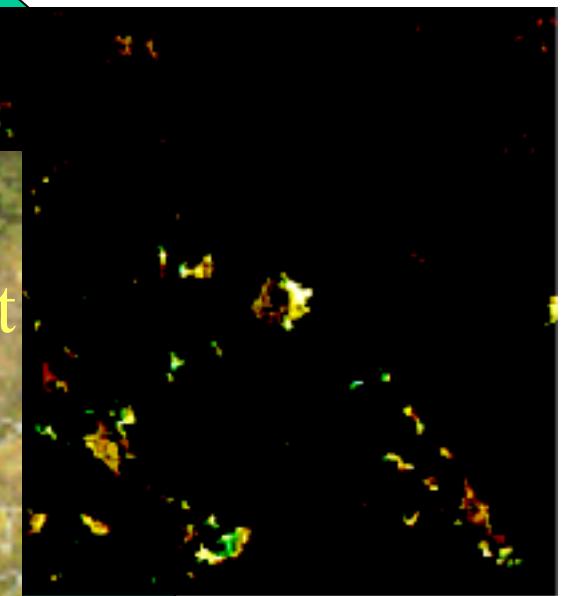
*Focus of this study*

Main Scale



The Delta

Component scale

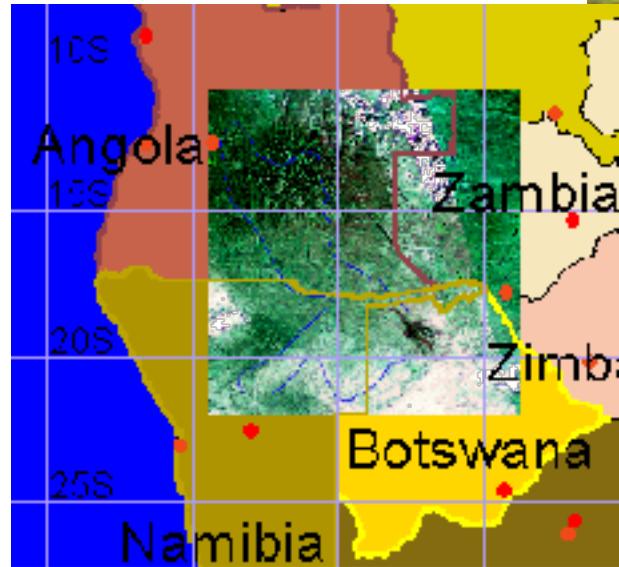


Islands, channels  
and lakes

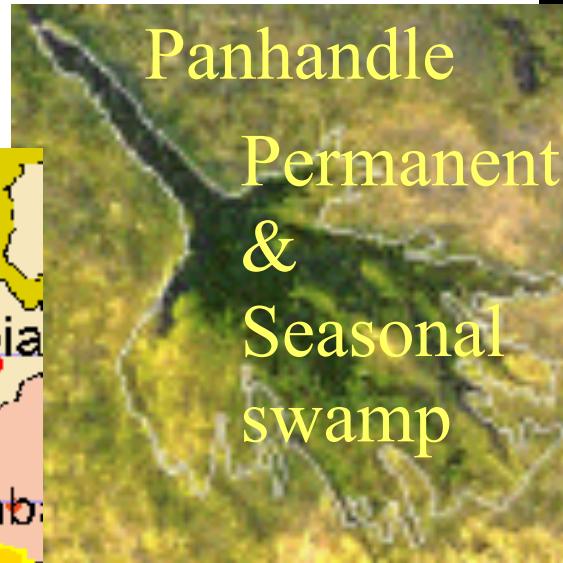
# Scale related problems of the Okavango Delta

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

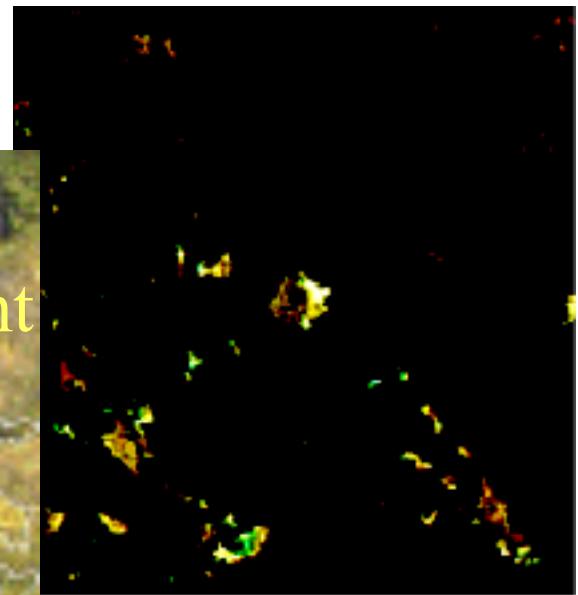
Poor quantitative  
estimates



The Catchment



The Delta



Islands, channels  
and lakes

# Objectives

Quantitative estimates and timing of the annual flood  
Quantitative estimates of the annaul vegetation cycle  
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

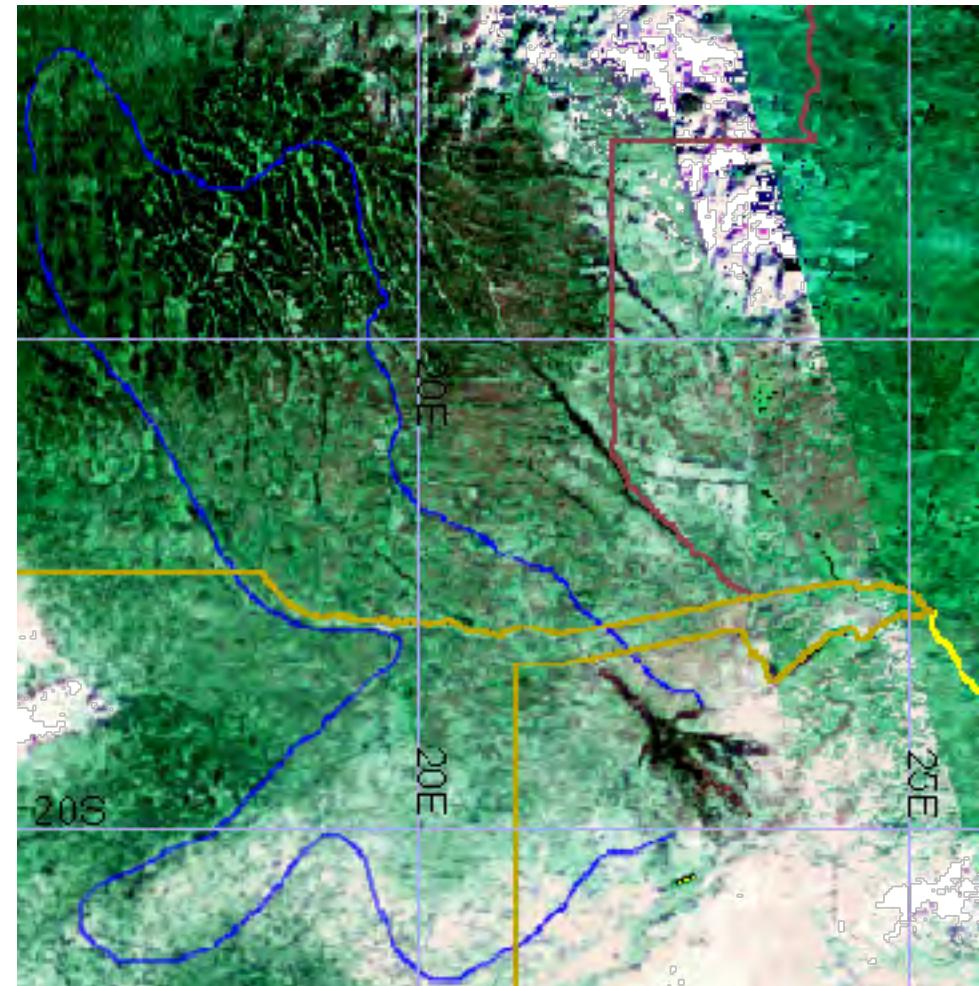
# Constraining scale capture – 1:1 miljon, 1-10 km grain size

➤ Digital Chart of the World, DCW

➤ GTOPO30

➤ NOAA-AVHRR  
(NDVI, cloud cover,  
cloud temperature)

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

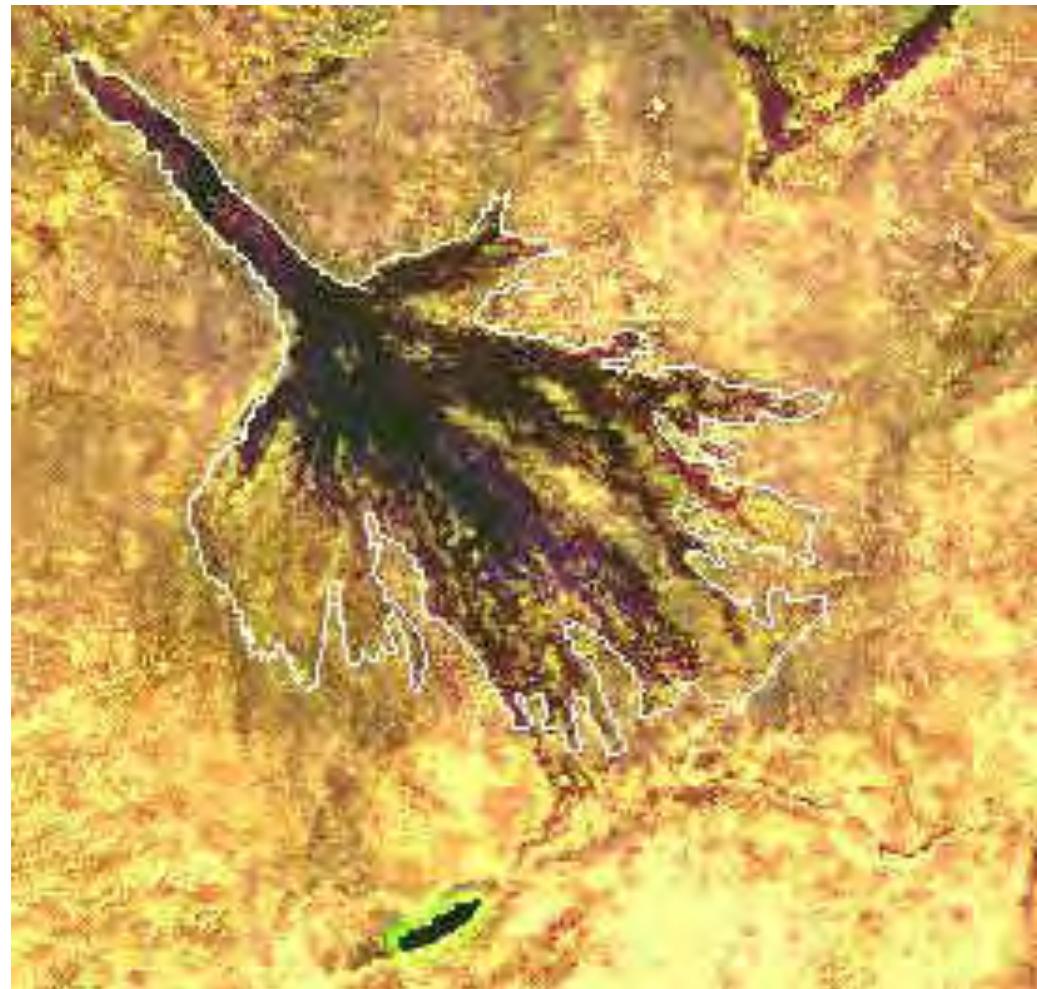
➤ GTOPO30

➤ NOAA-AVHRR

NDVI, water area,  
cloud cover

➤ ERS2-ATSR

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

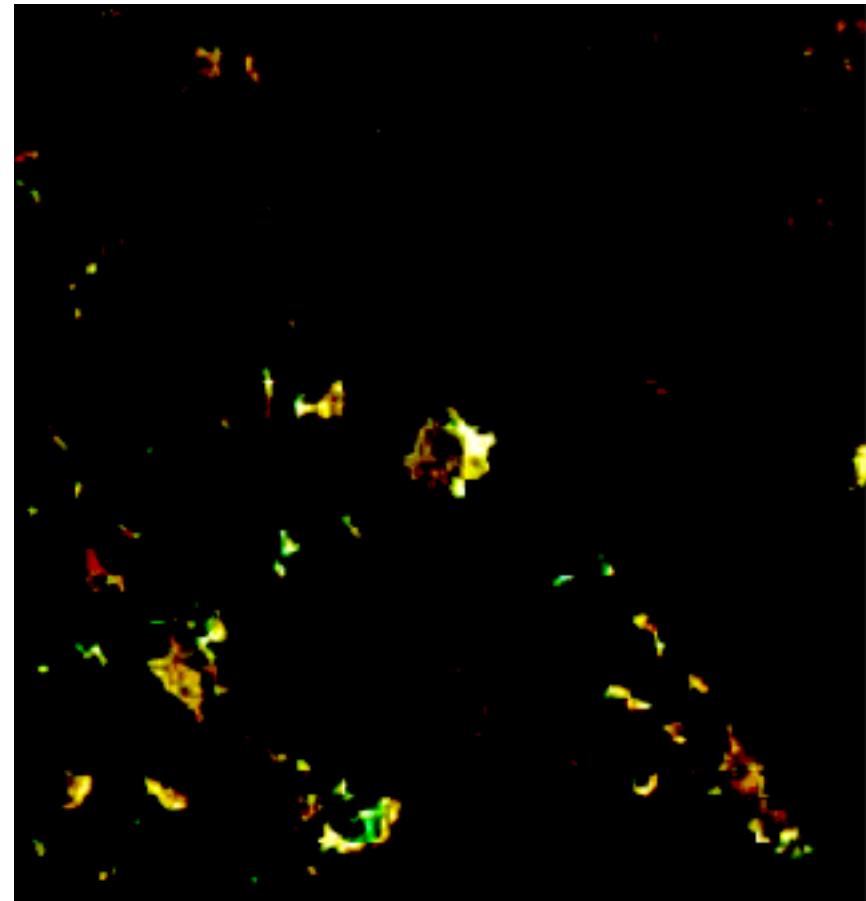


## Component scale

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

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

False colour composite  
from Landsat TM,  
July 1994



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

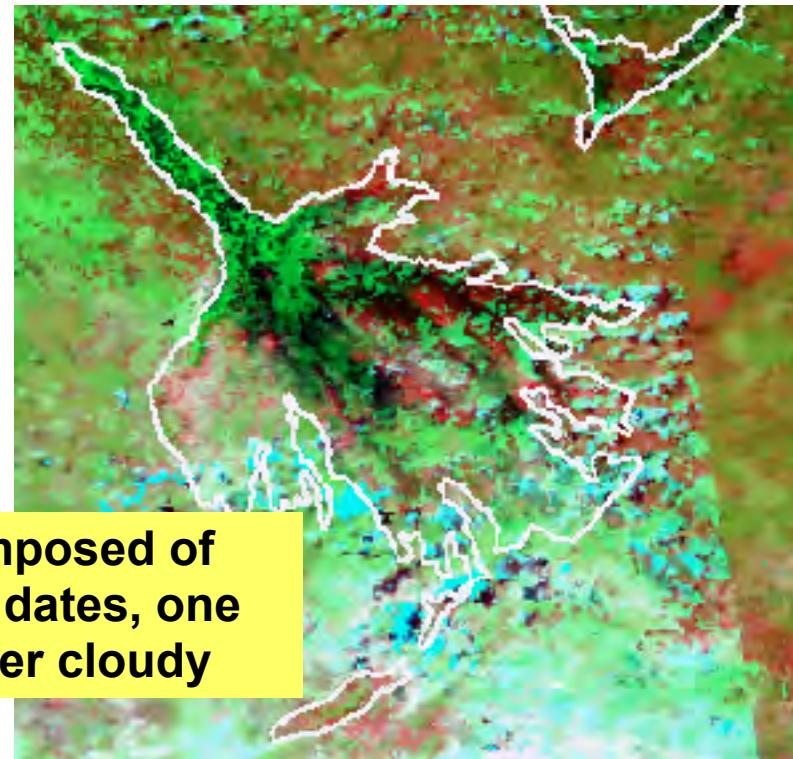
Image  
composition:

Blue = B1

Green = B2

Red = B3

(B = Band)



Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

1992

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

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composition:

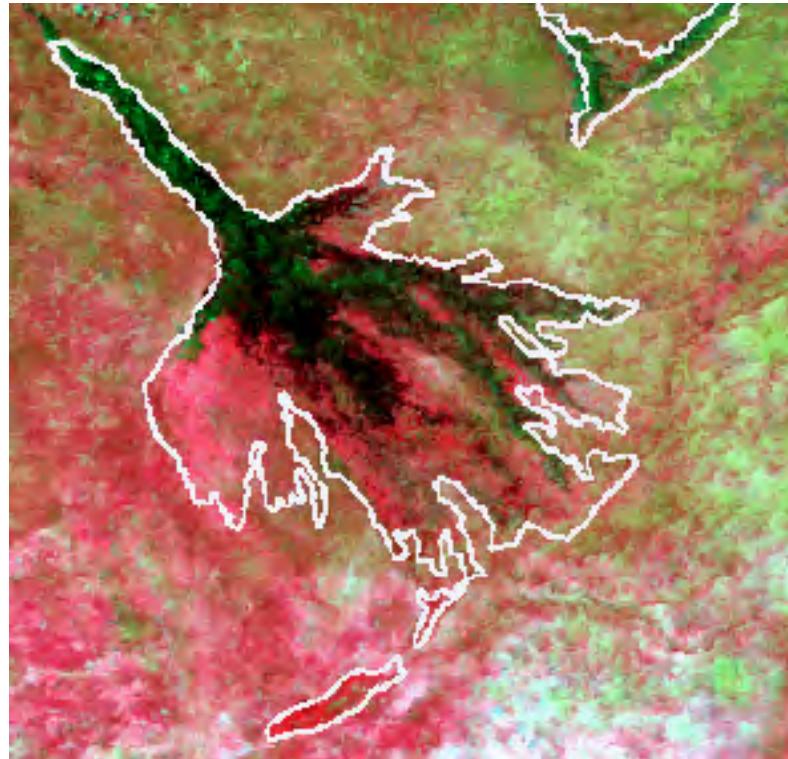
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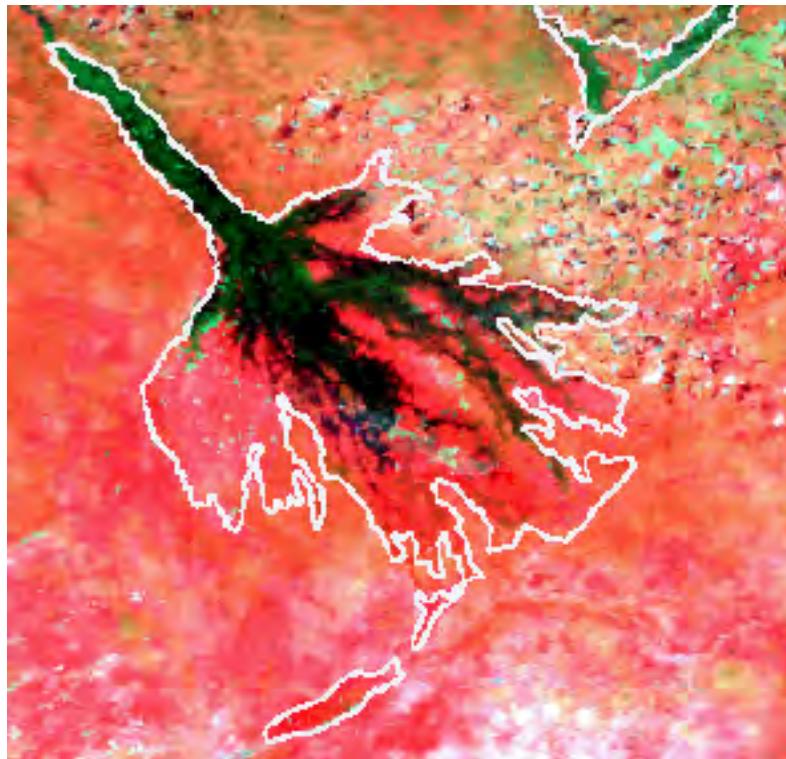
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1992

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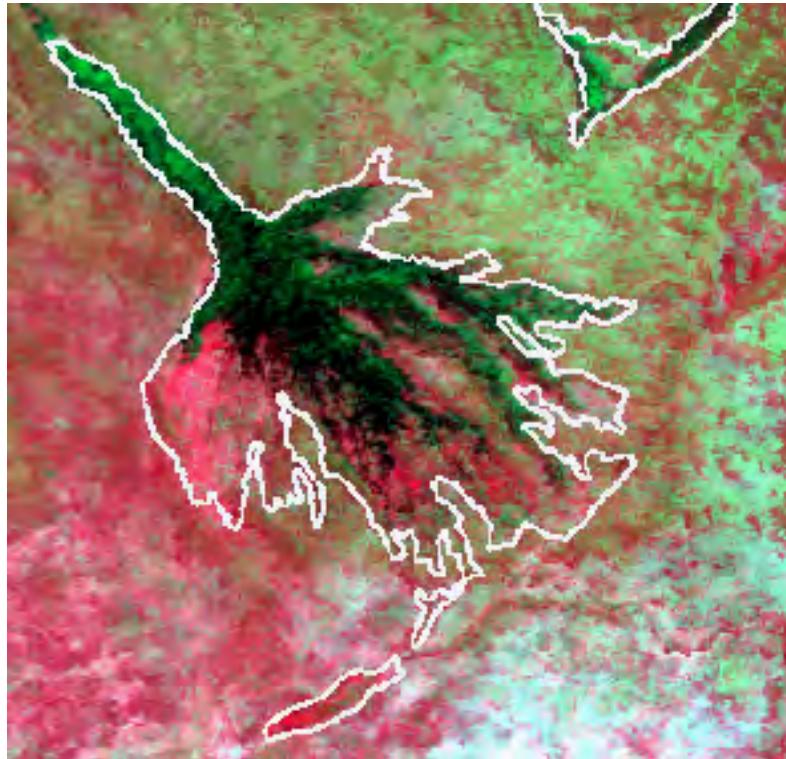
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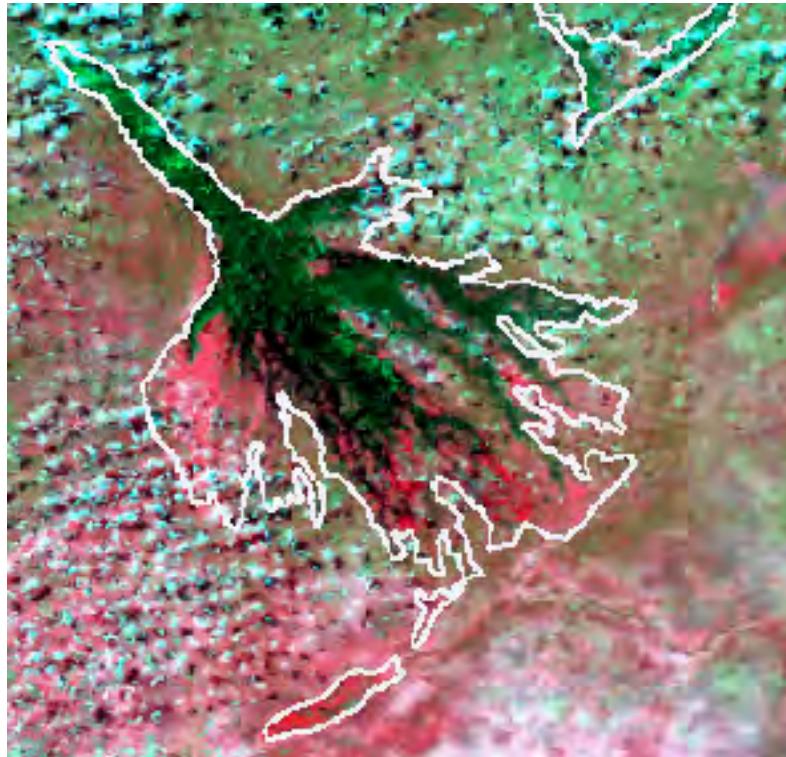
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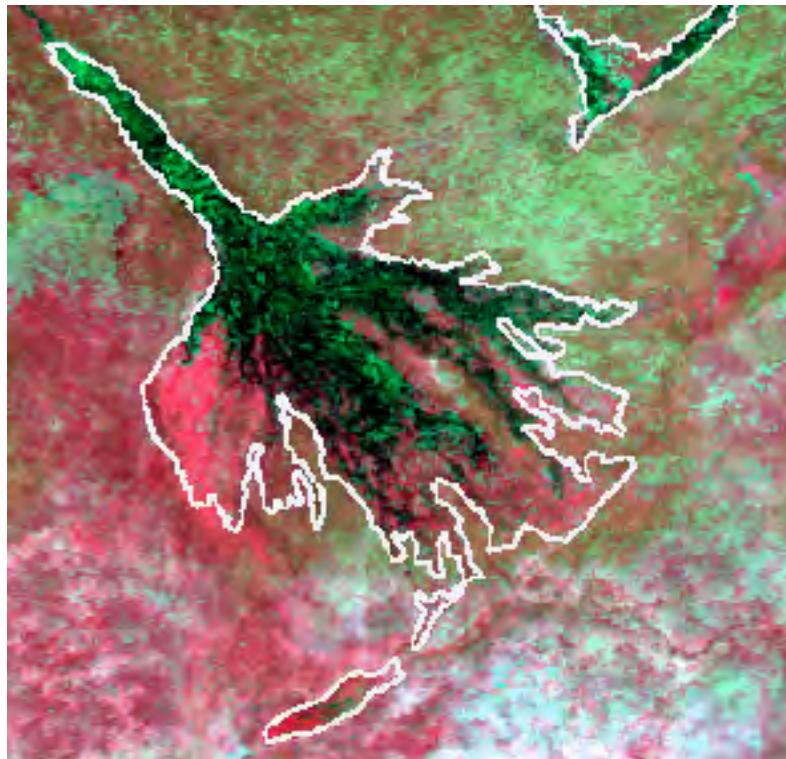
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1992

JAN FEB MAR APR MA<sub>Y</sub> JUN JUL AUG SEP OCT NOV DEC

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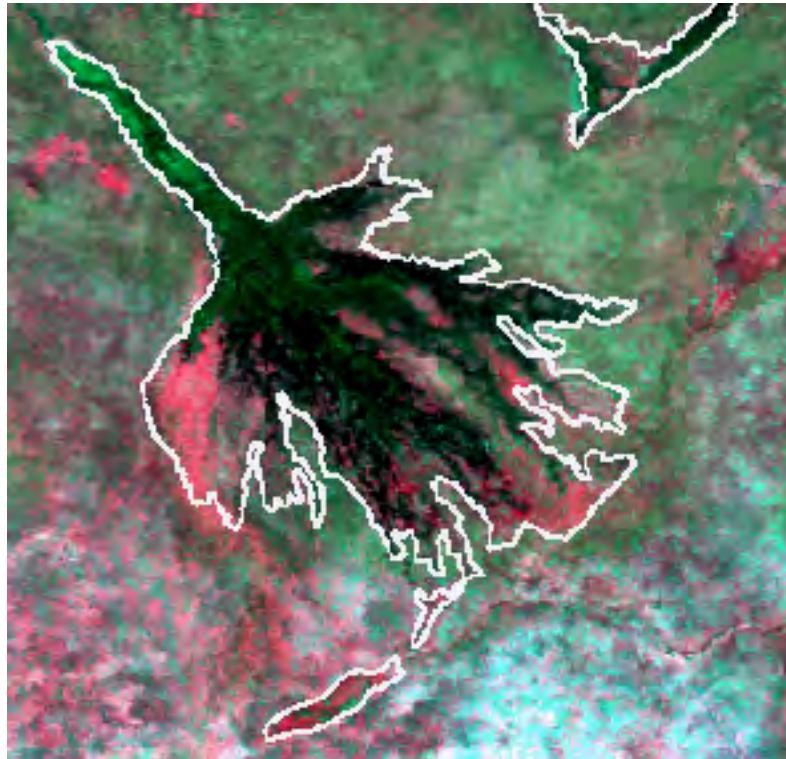
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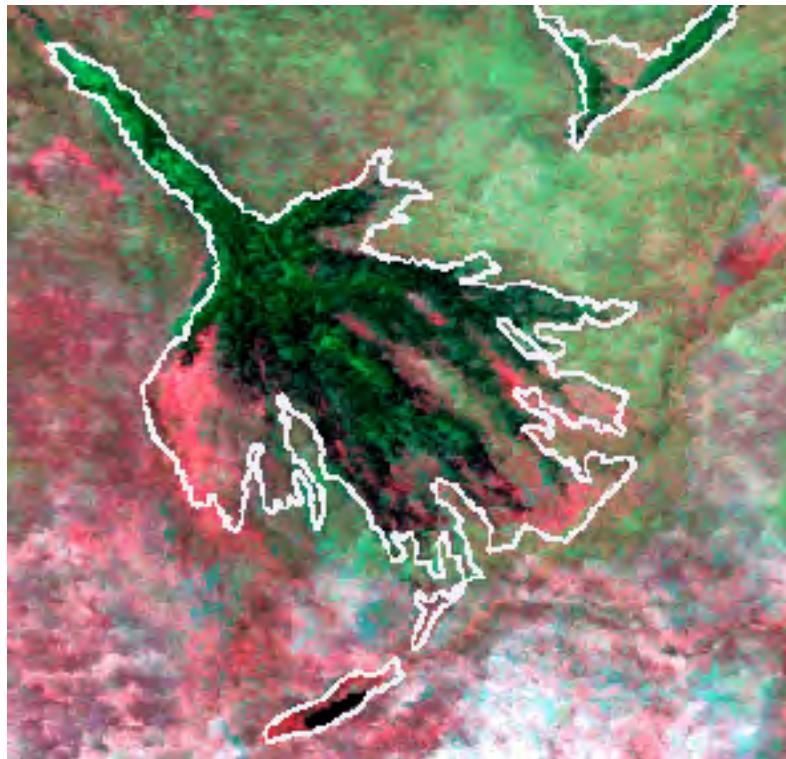
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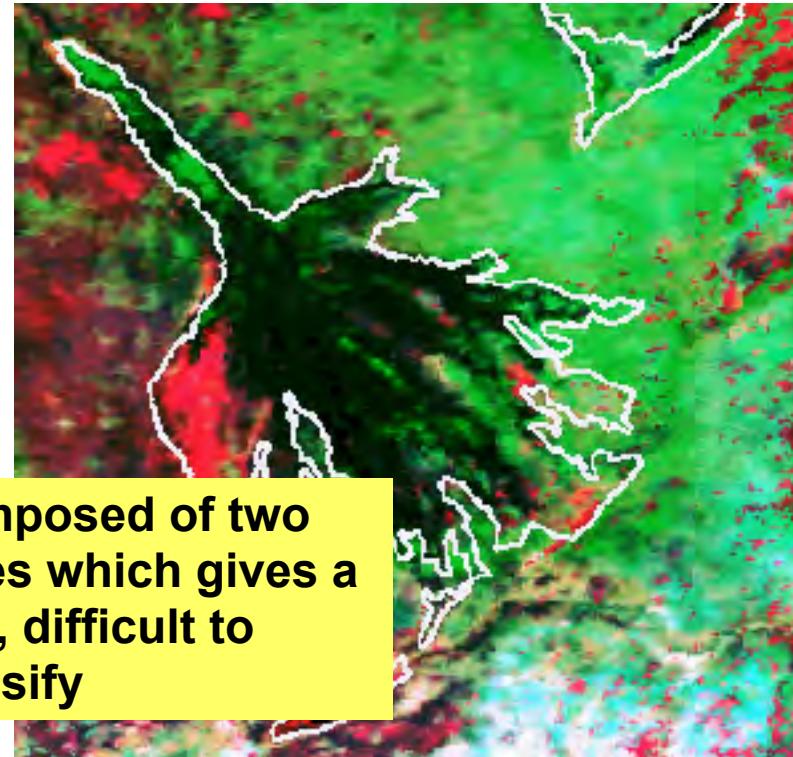
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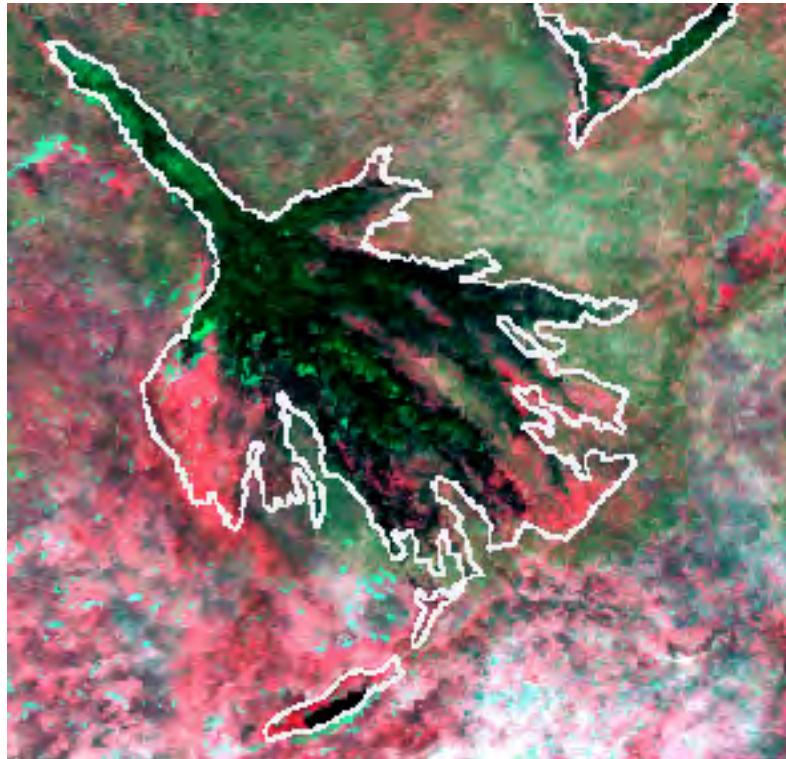
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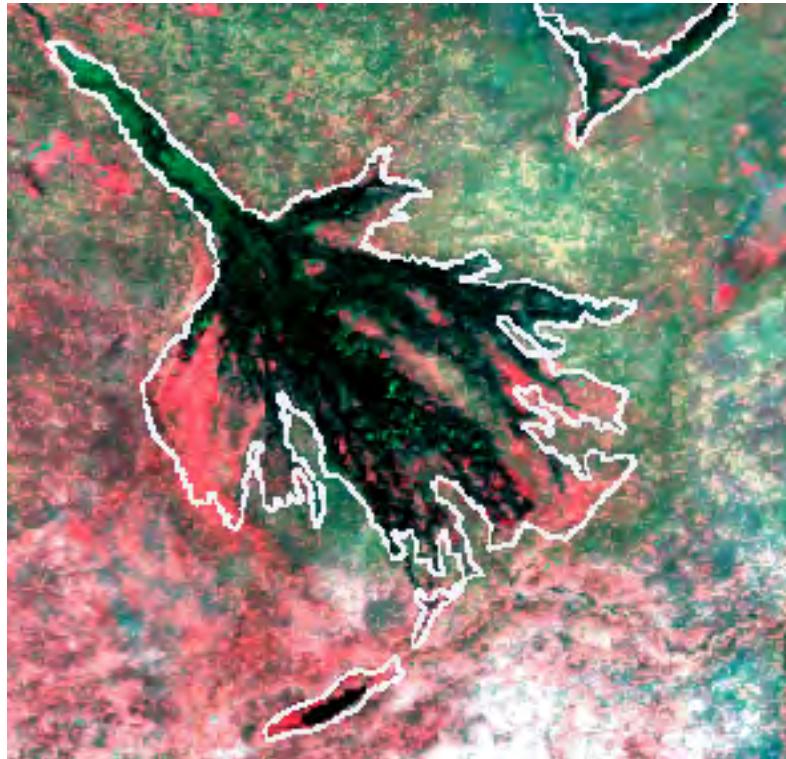
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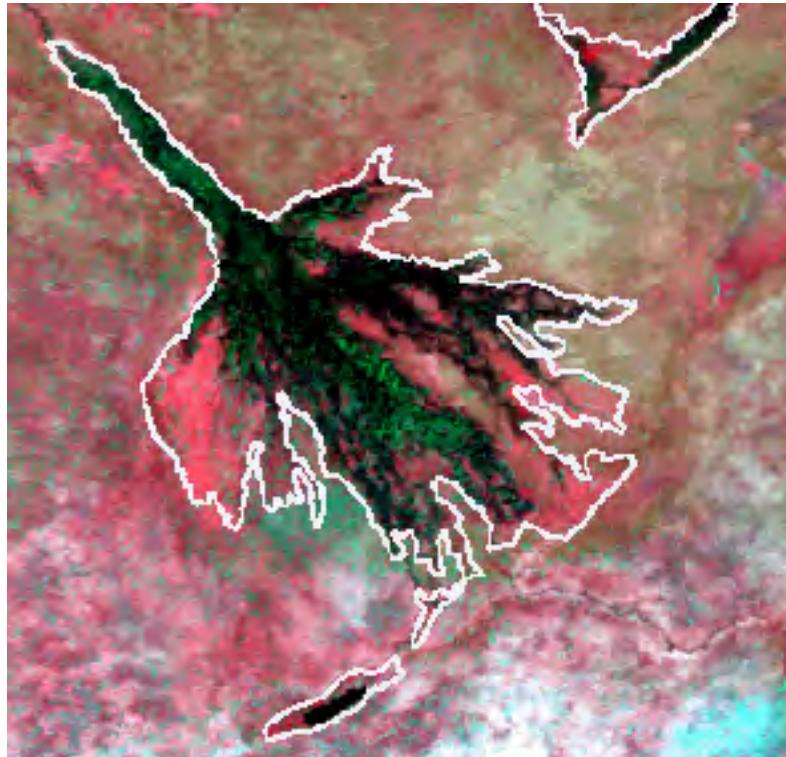
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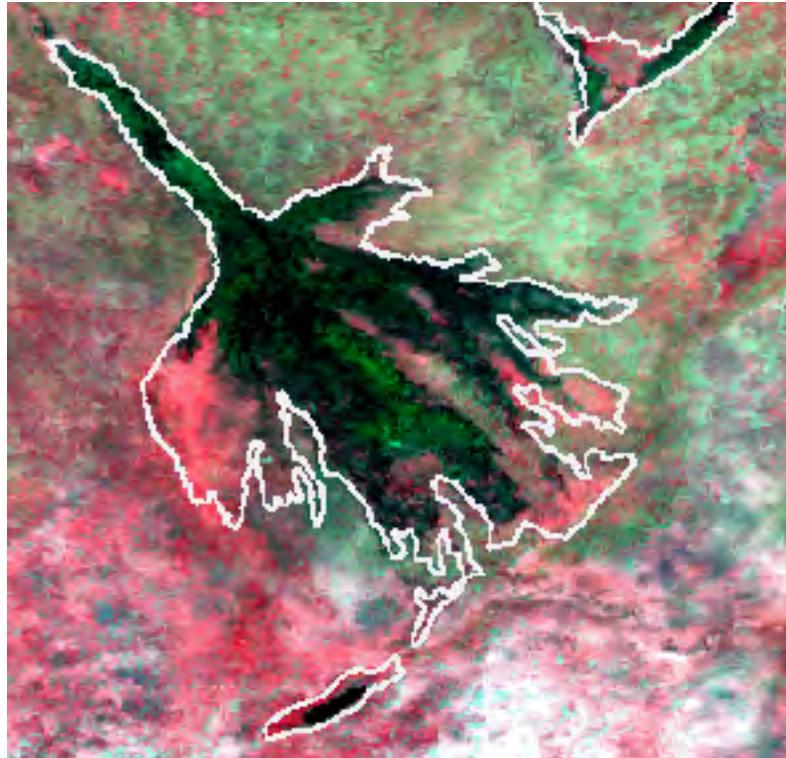
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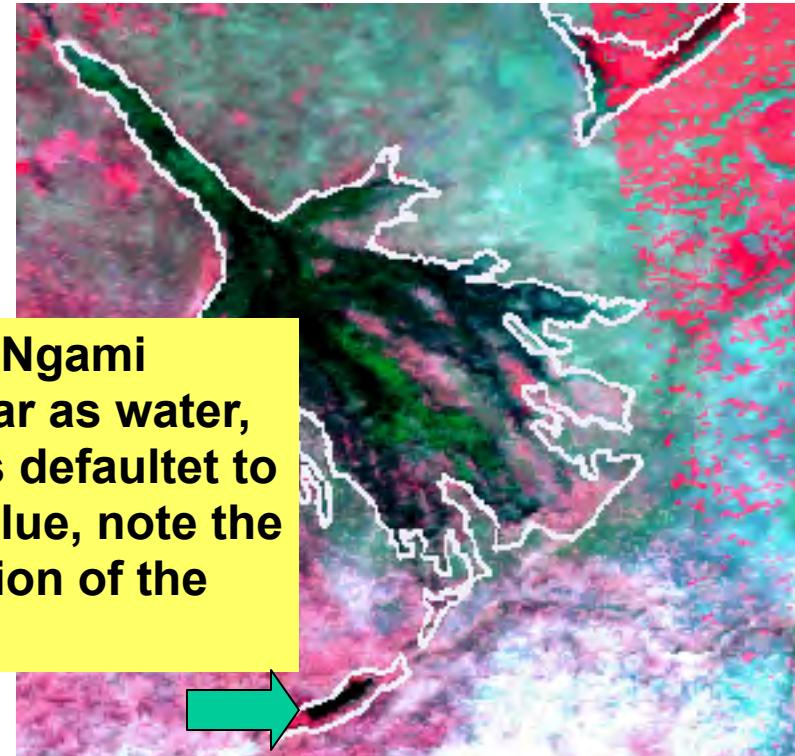
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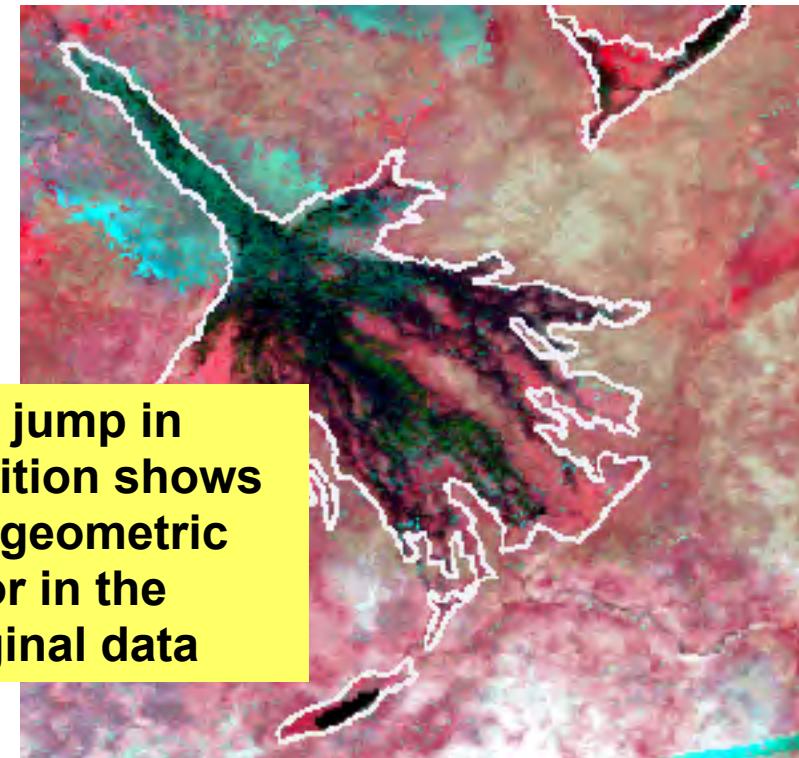
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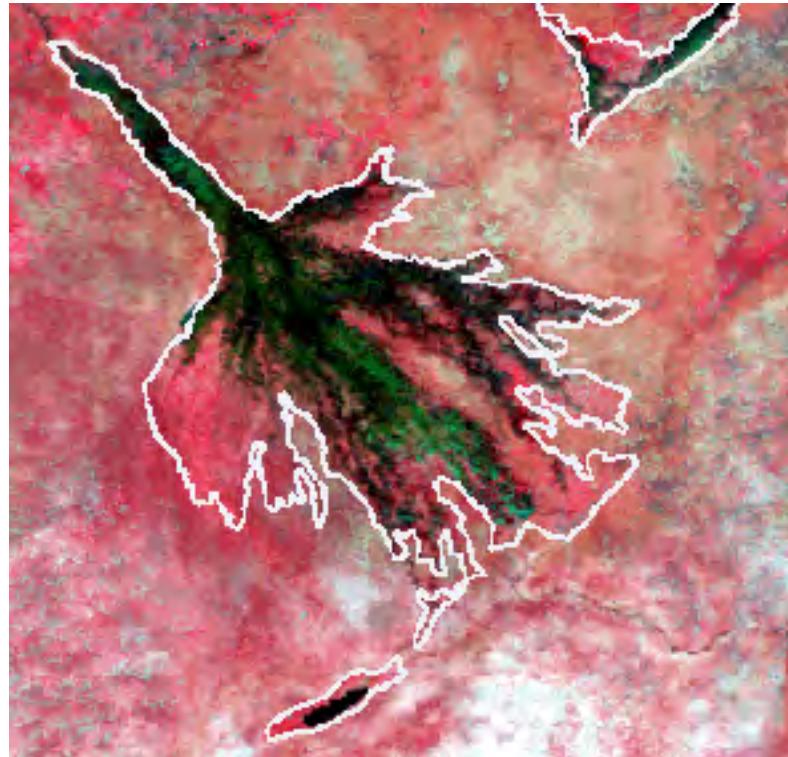
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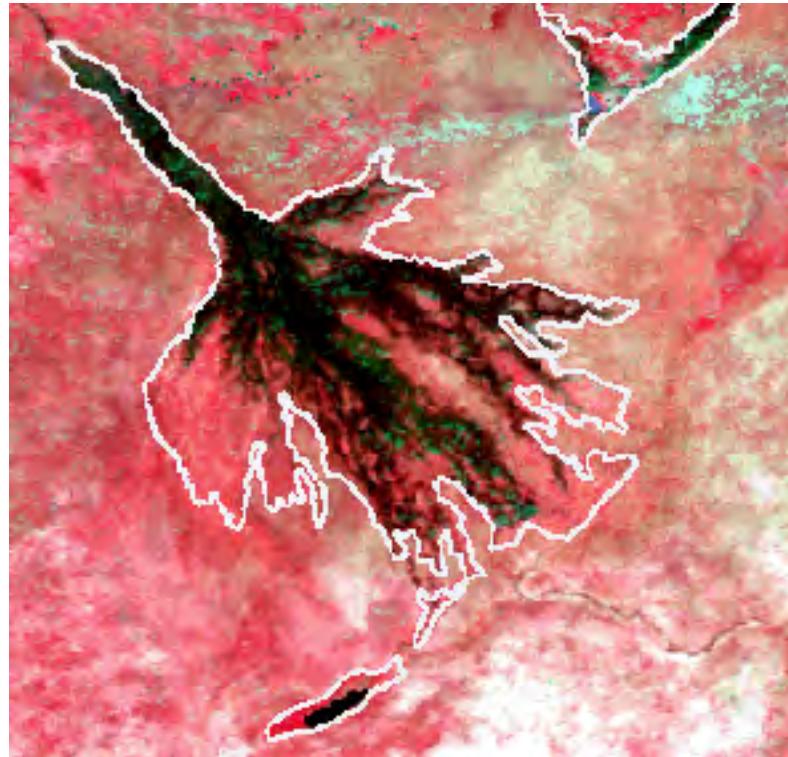
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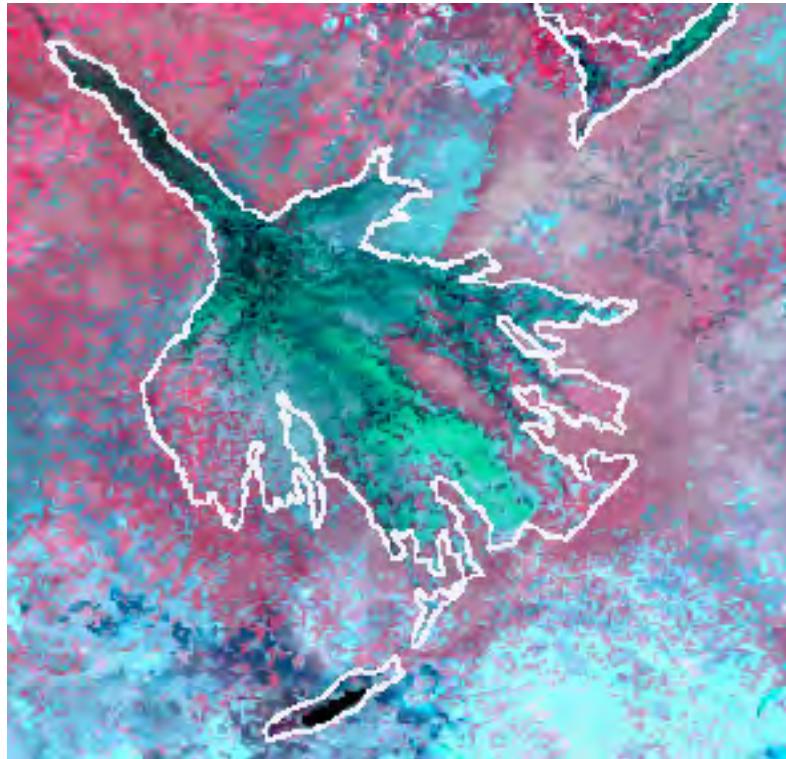
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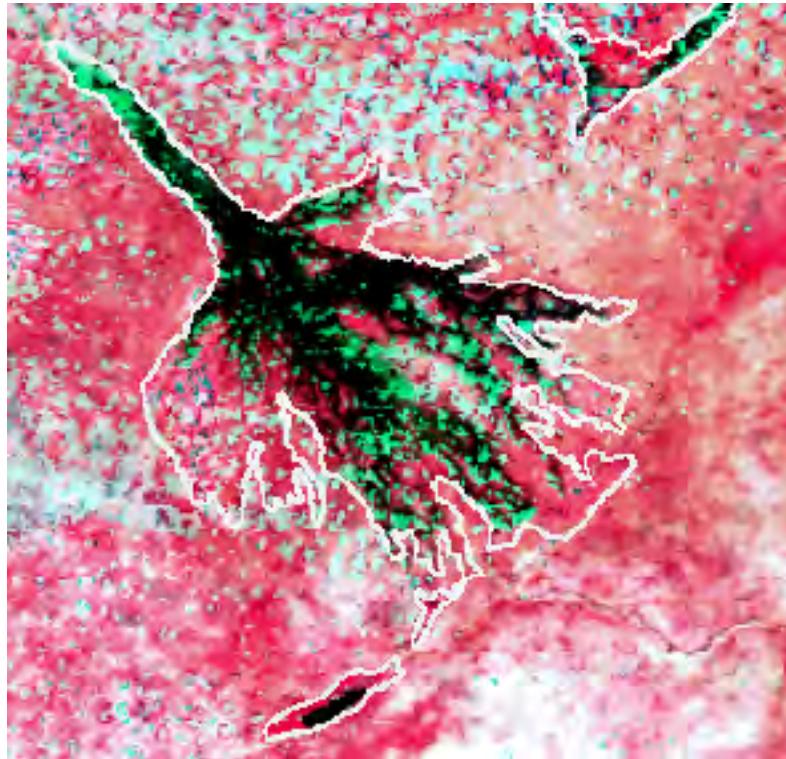
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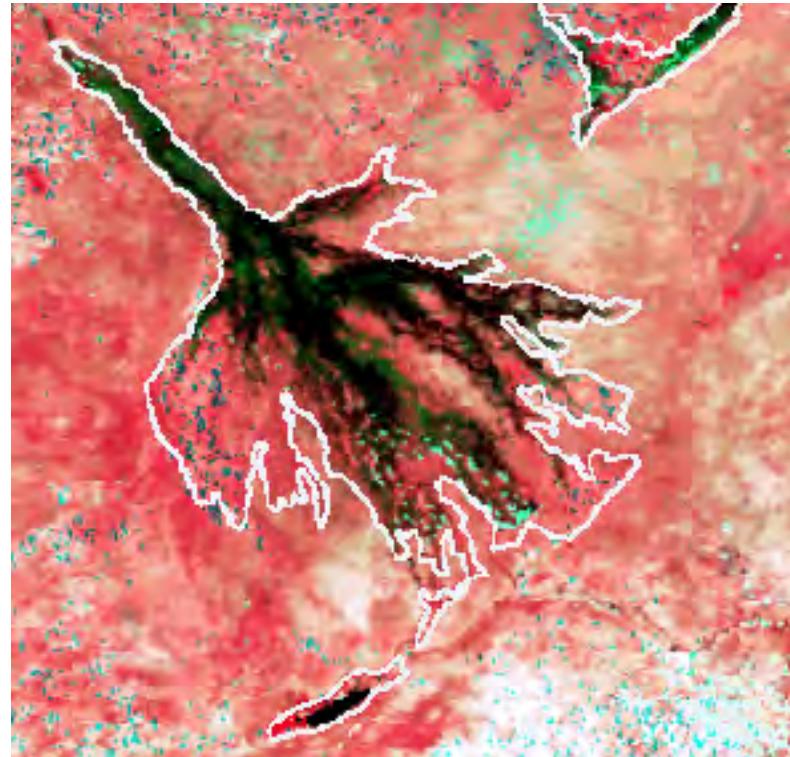
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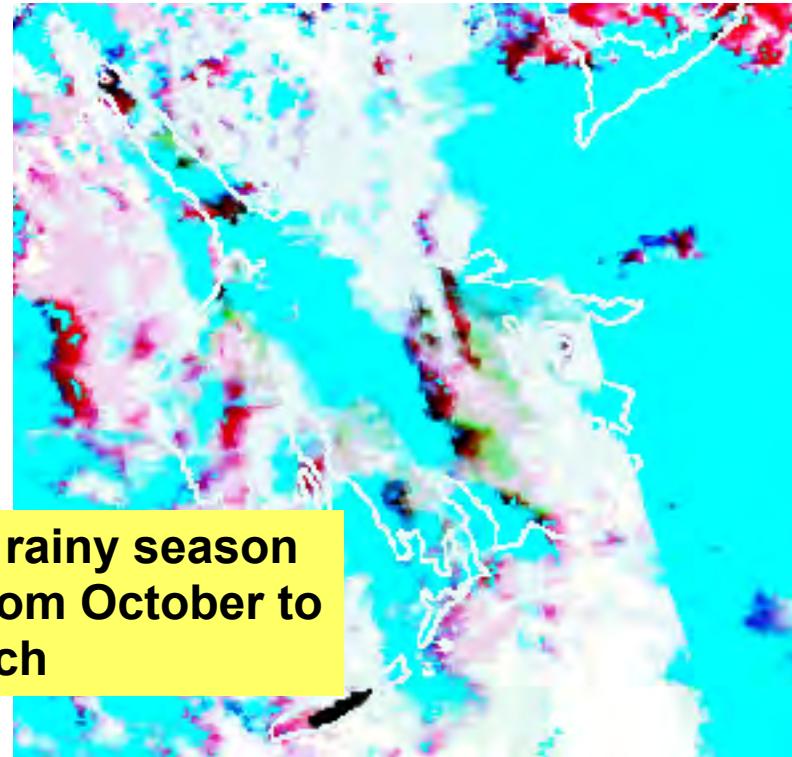
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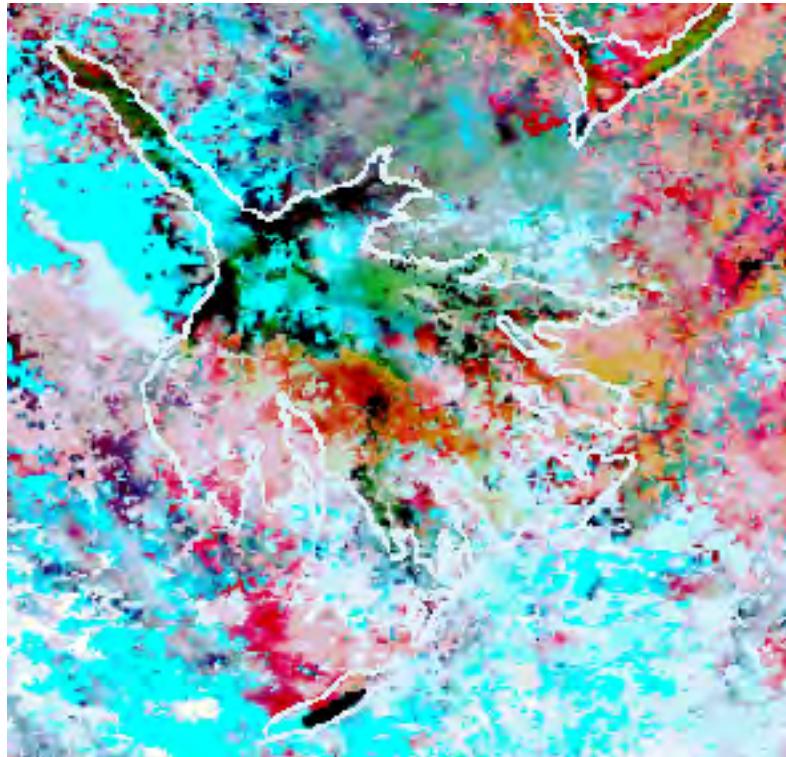
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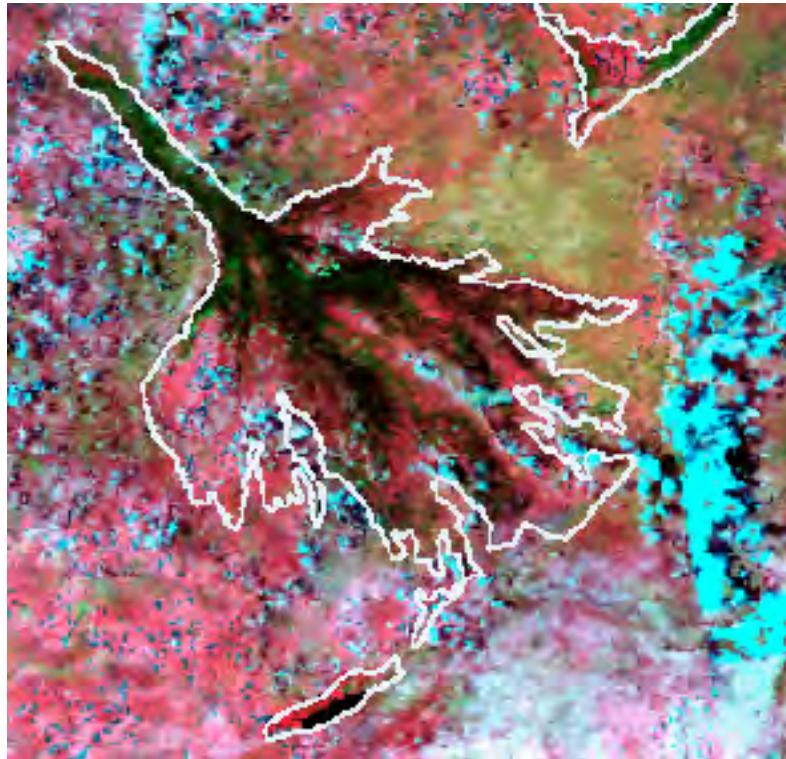
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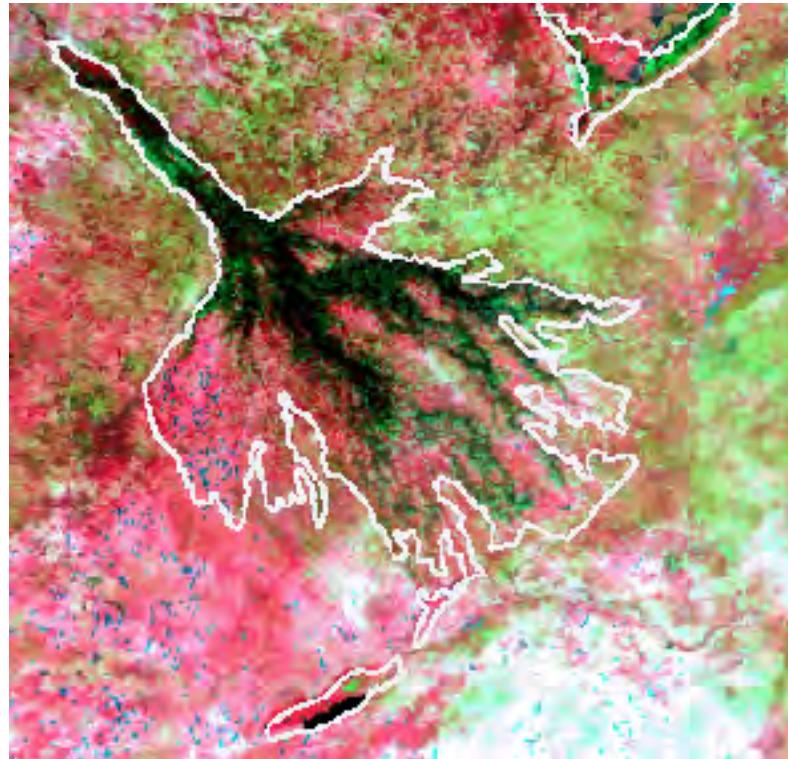
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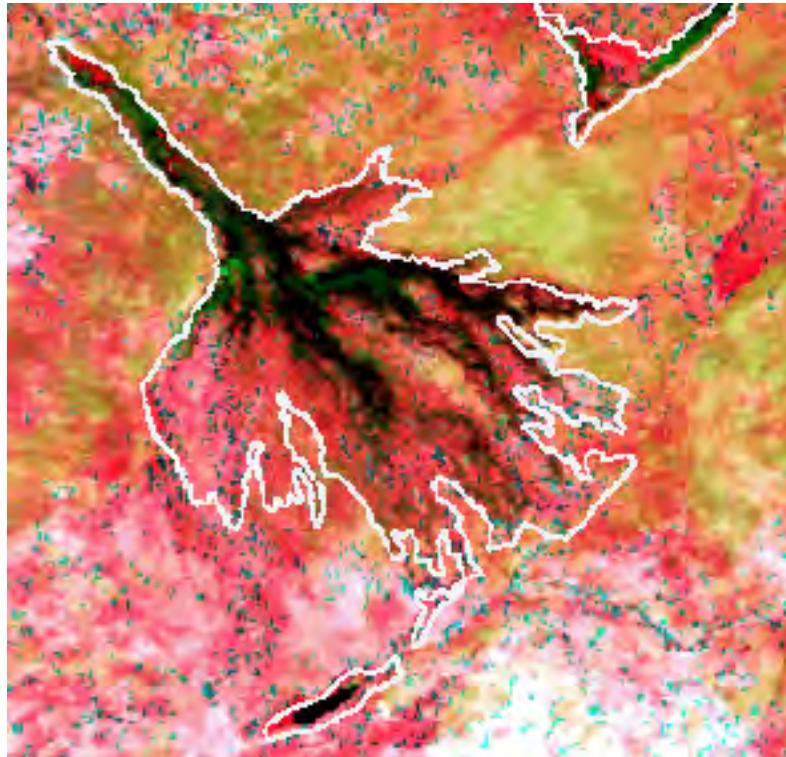
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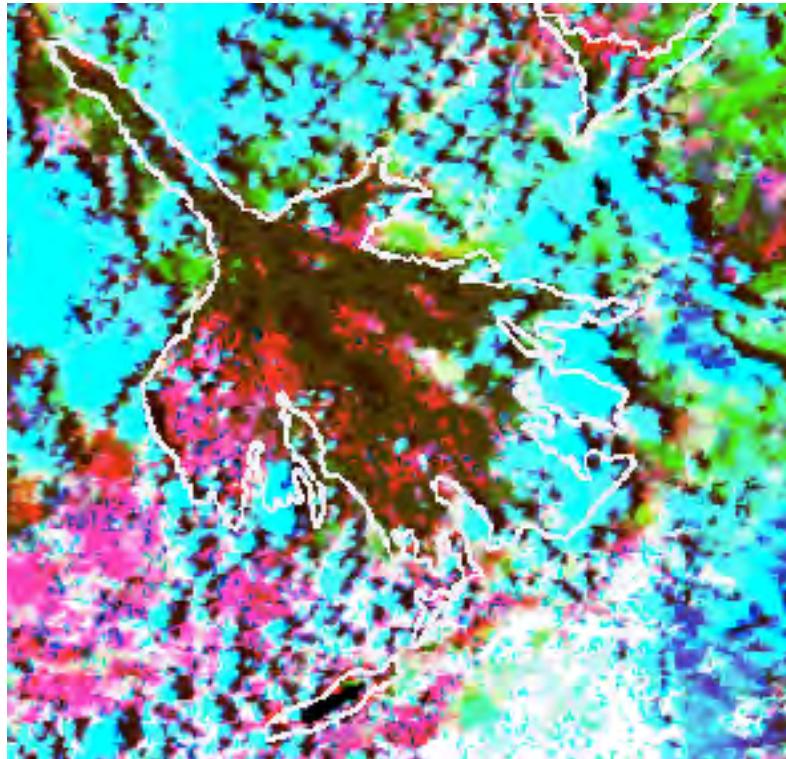
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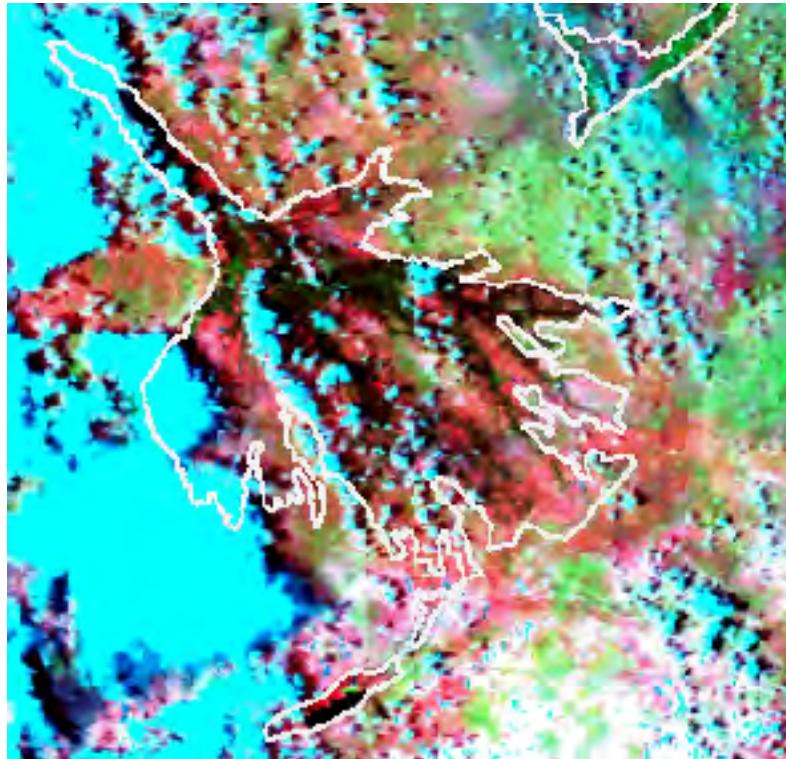
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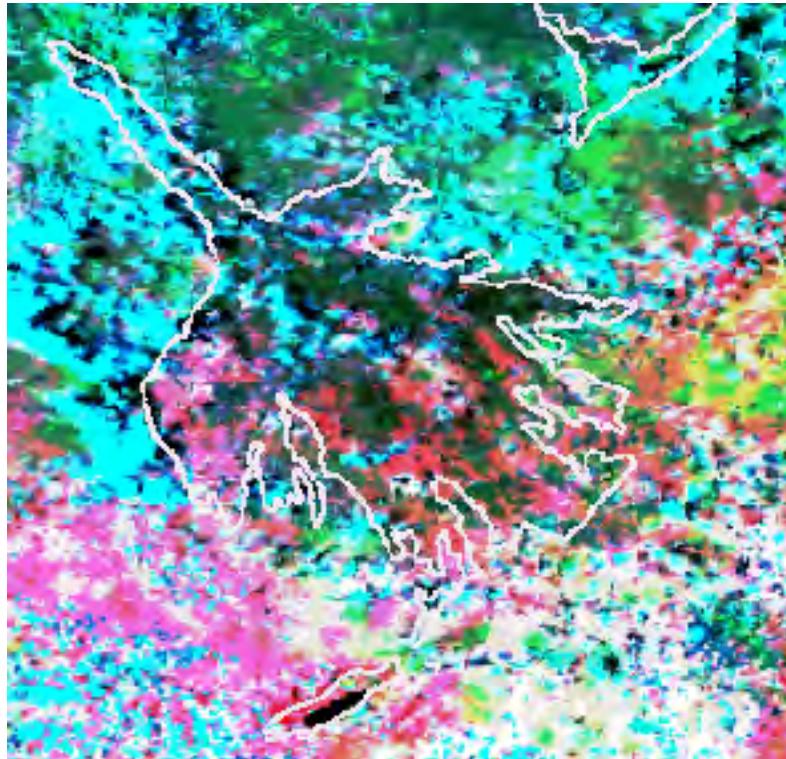
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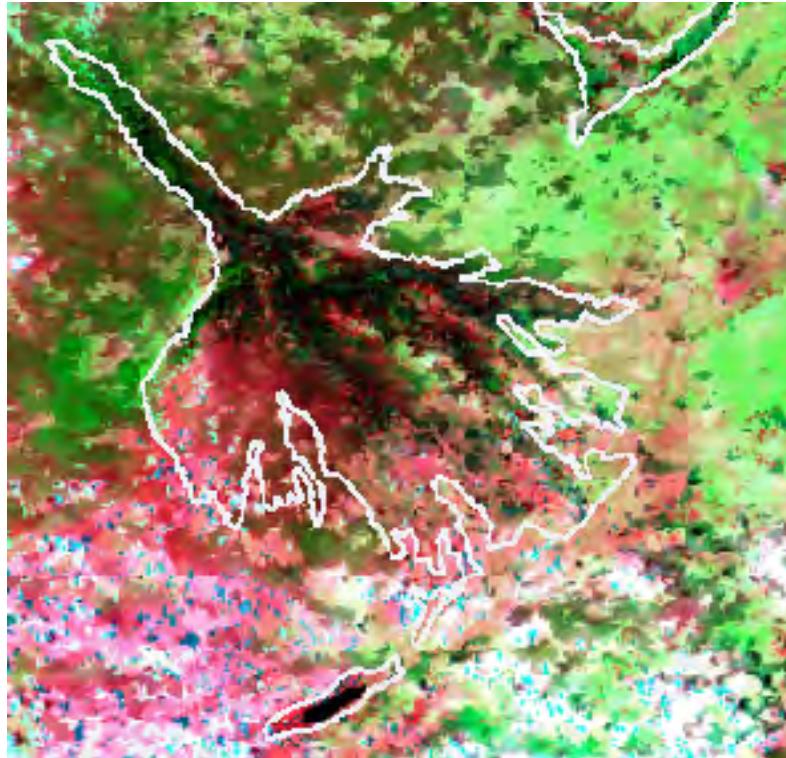
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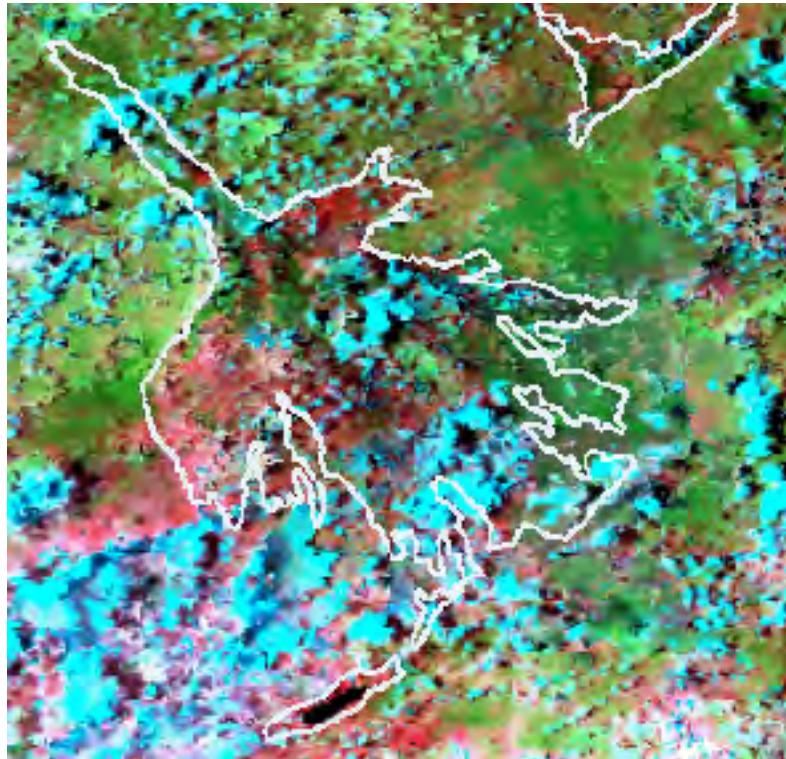
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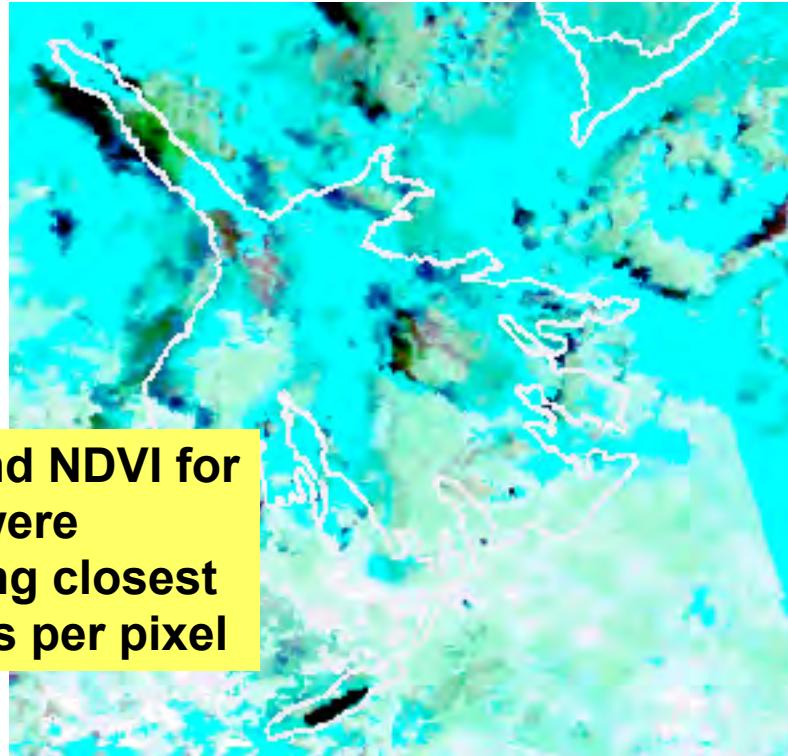
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Image  
composition:

Blue = B1

Green = B2

Red = B3  
(B = Water cover and NDVI for  
cloudy dates were  
calculated using closest  
cloudfree dates per pixel)



1993

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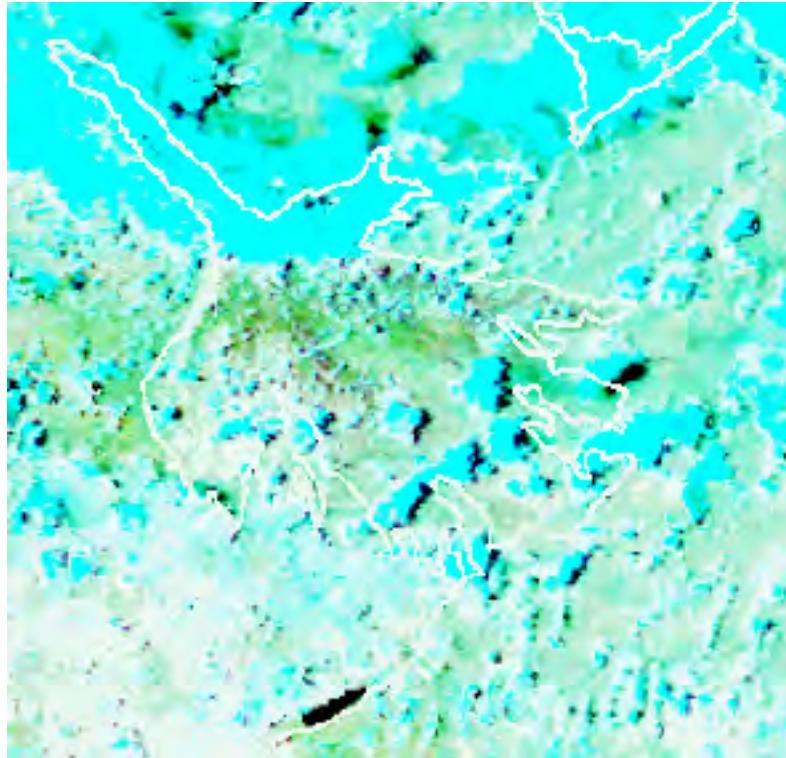
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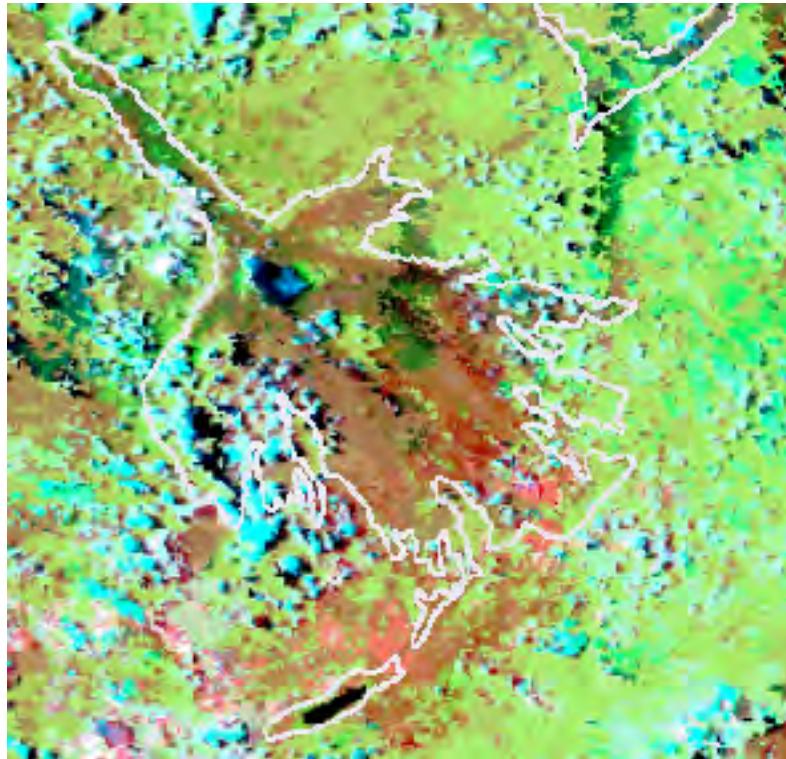
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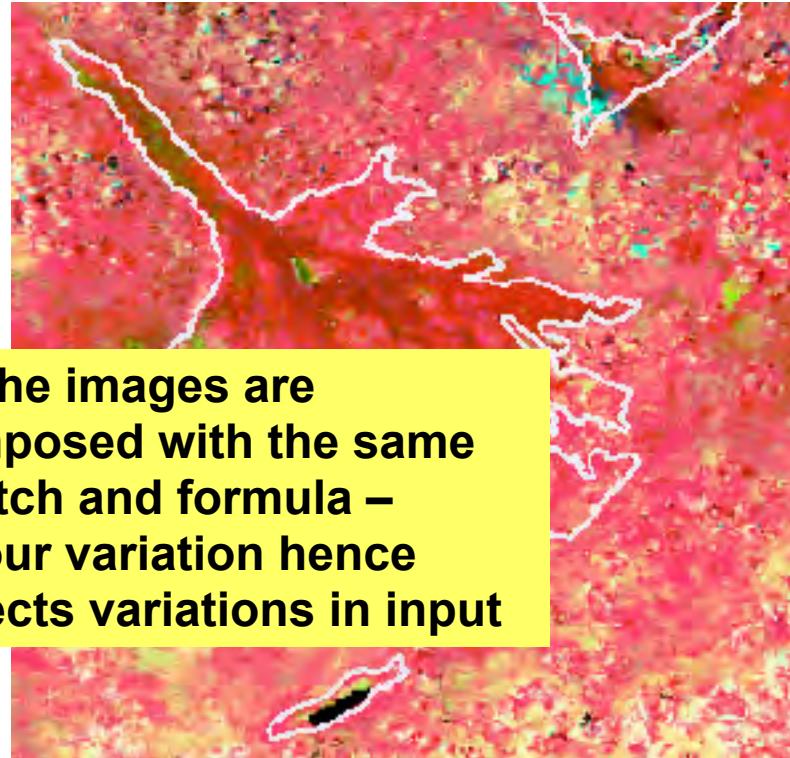
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B3 = IR

(IR = Infra Red)

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

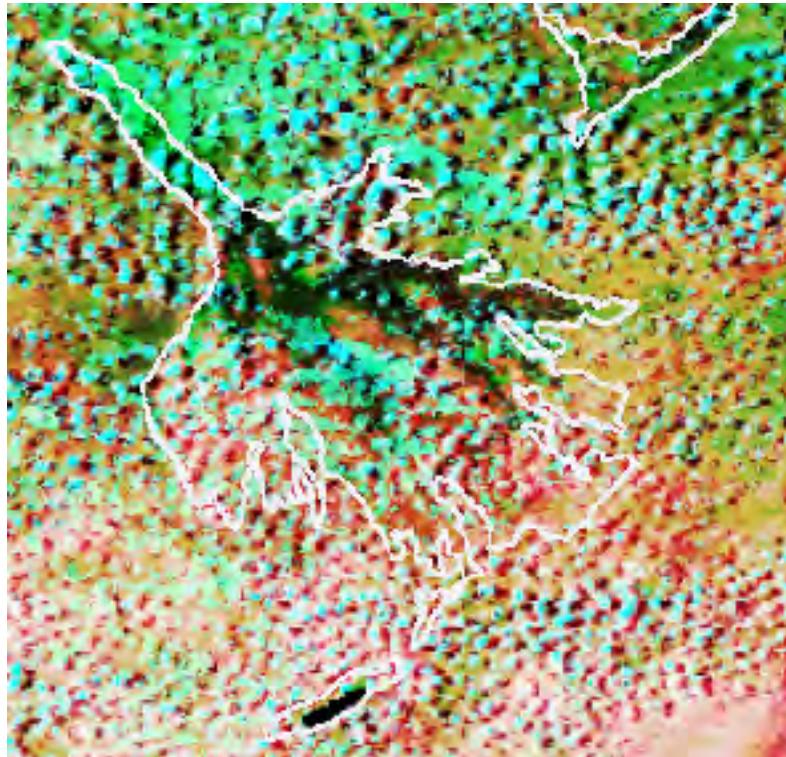
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

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

NOAA-AVHRR 10 day composite of the

## Okavango Delta

Image  
composition:

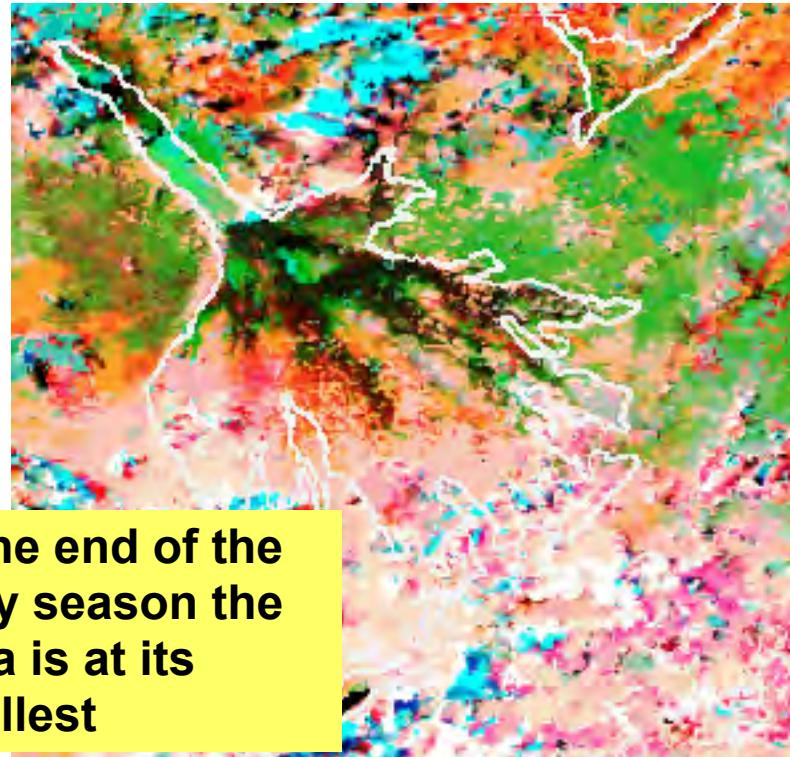
Blue = B1

Green = B2

Red = B3

(B = Band)

↑  
N



Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

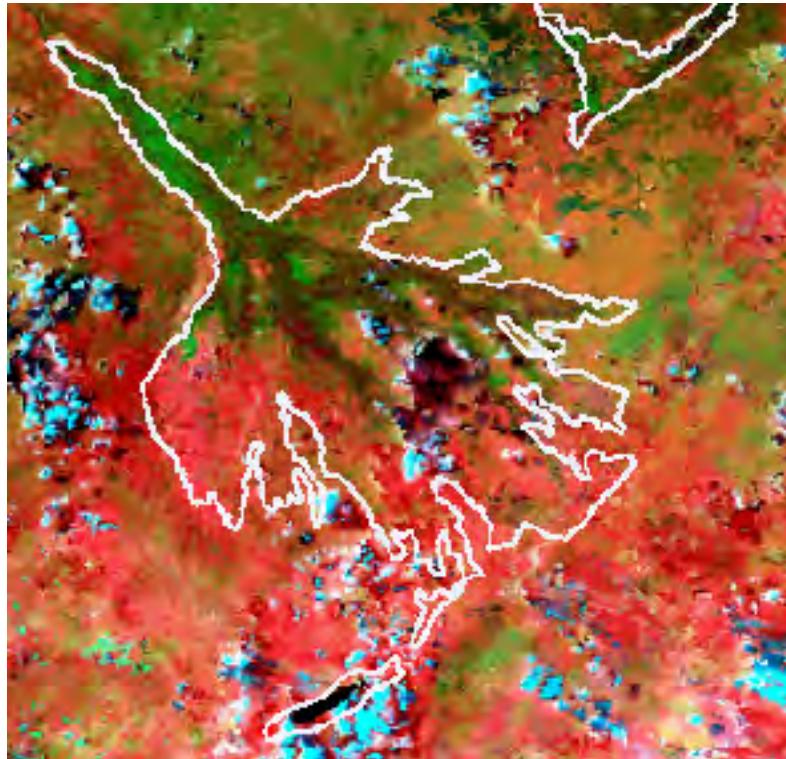
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

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

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

NOAA-AVHRR 10 day composite of the

## Okavango Delta

Image  
composition:

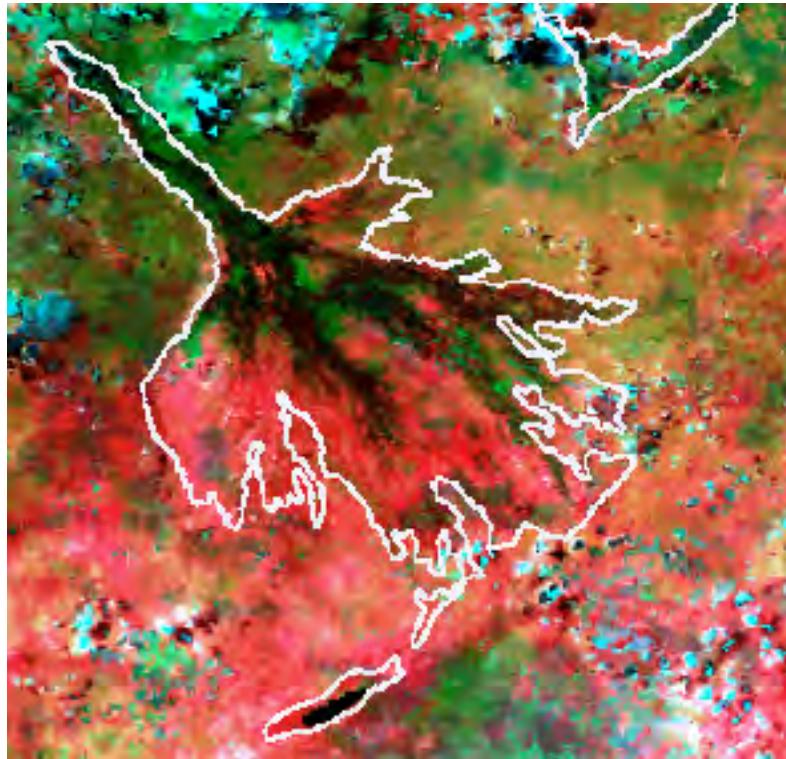
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

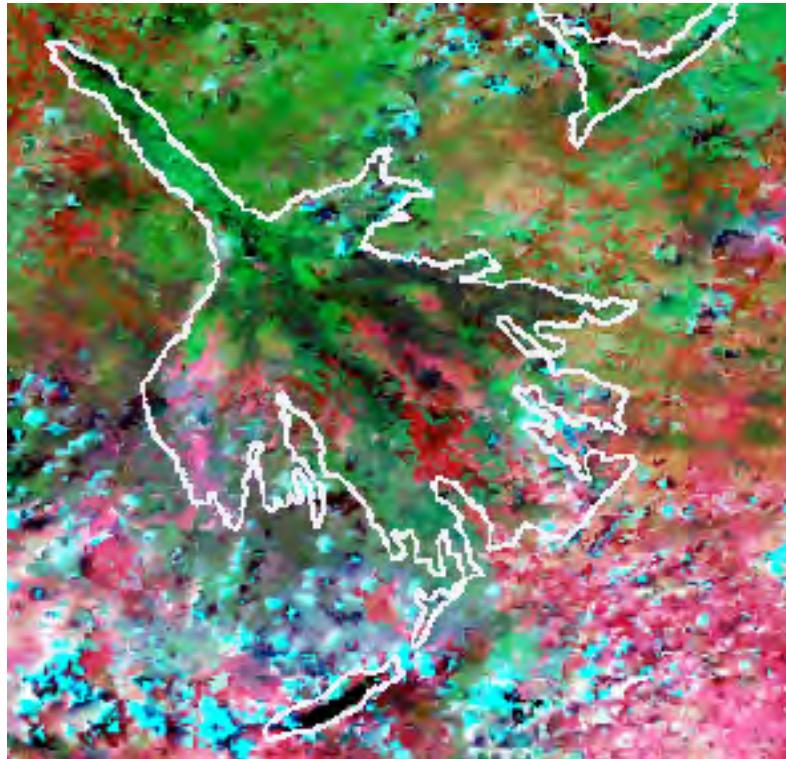
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

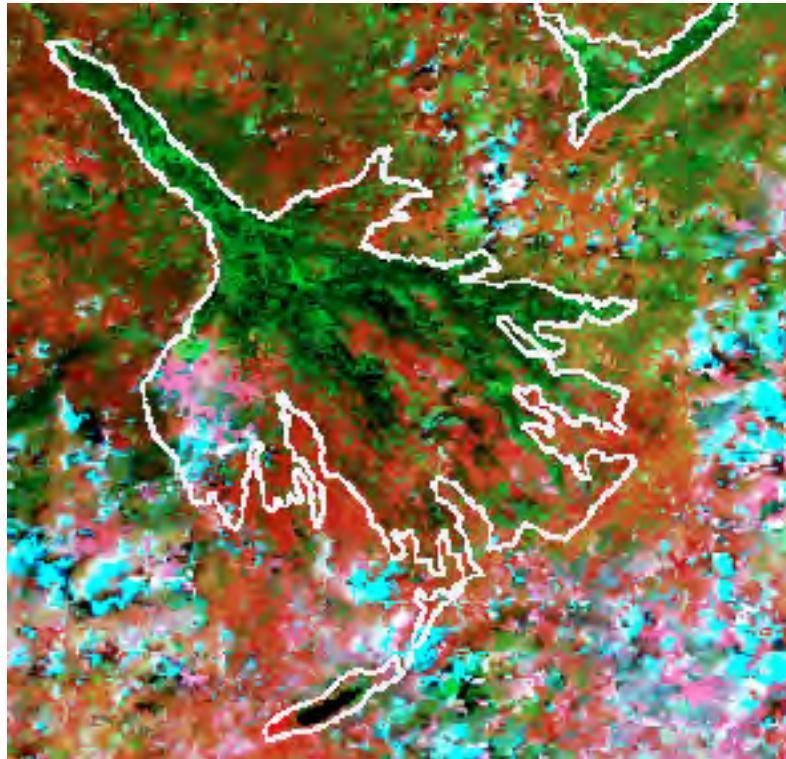
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

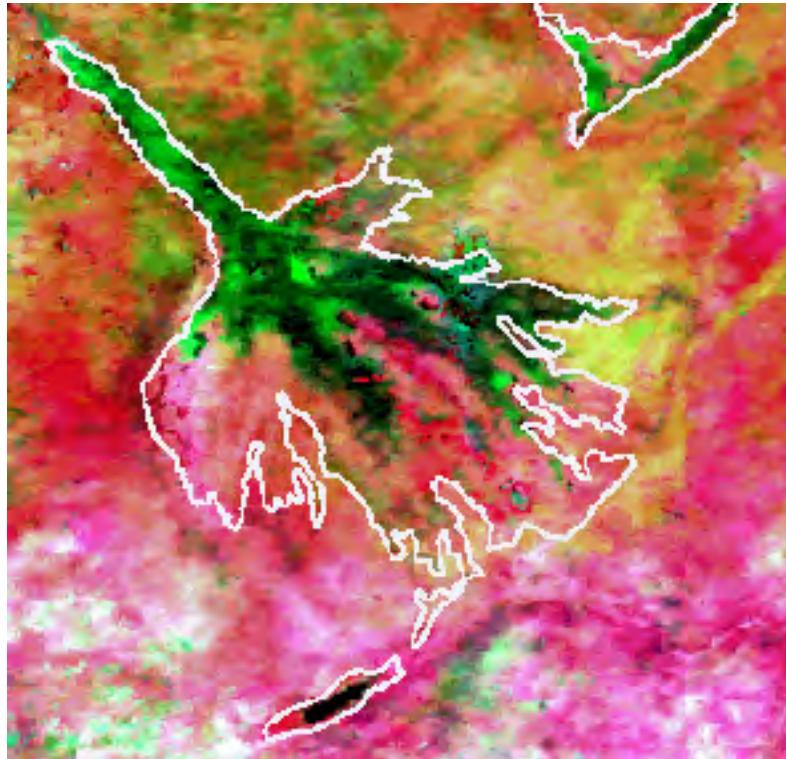
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

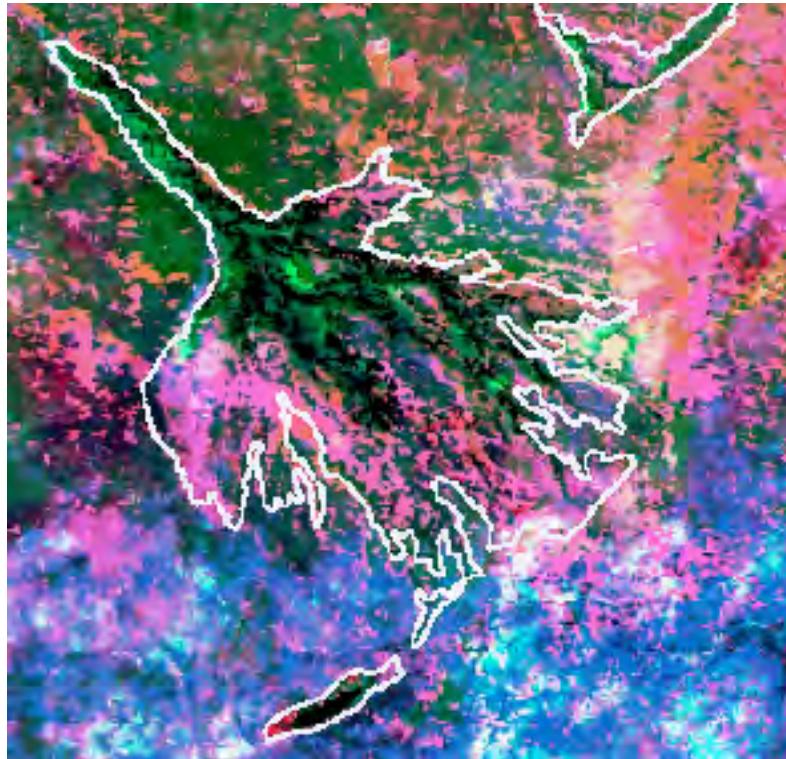
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



Band  
wavelength:  
B1 = Green  
B2 = Near IR  
B3 = IR  
(IR = Infra Red)

100 Km

JAN FEB MAR APR MA<sub>Y</sub> JUN JUL AUG SEP OCT NOV DEC

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

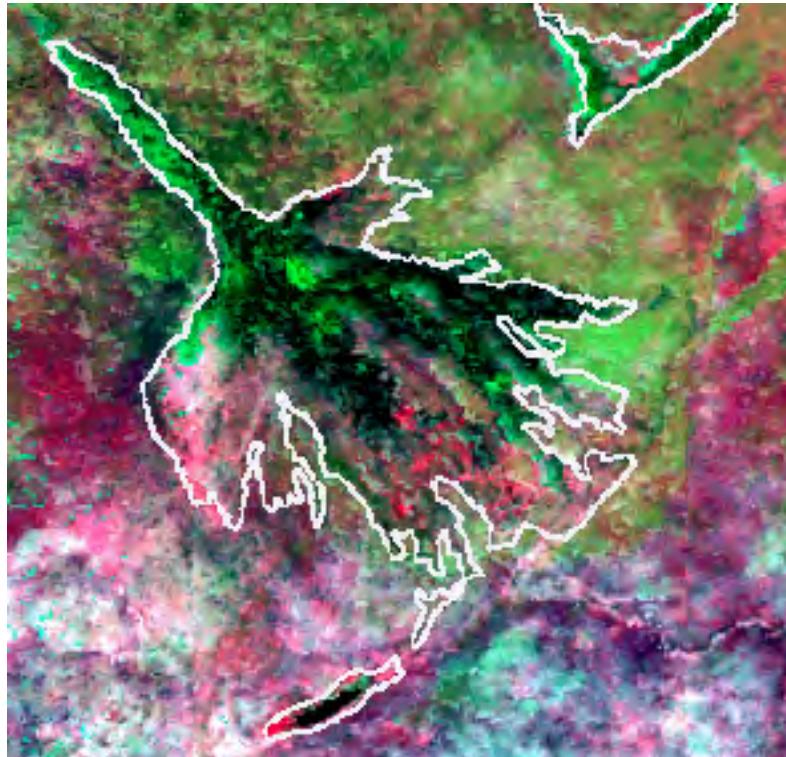
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

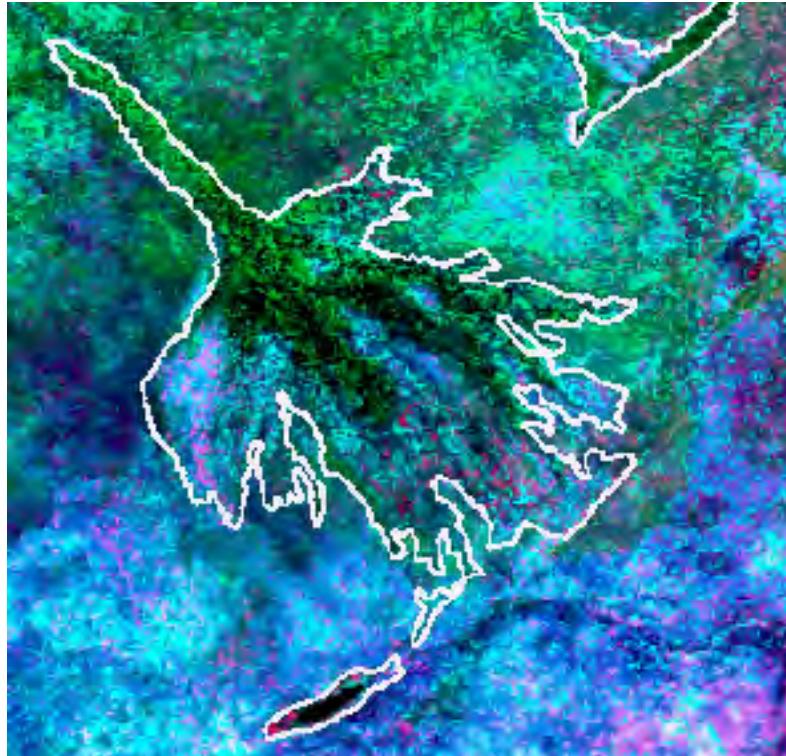
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

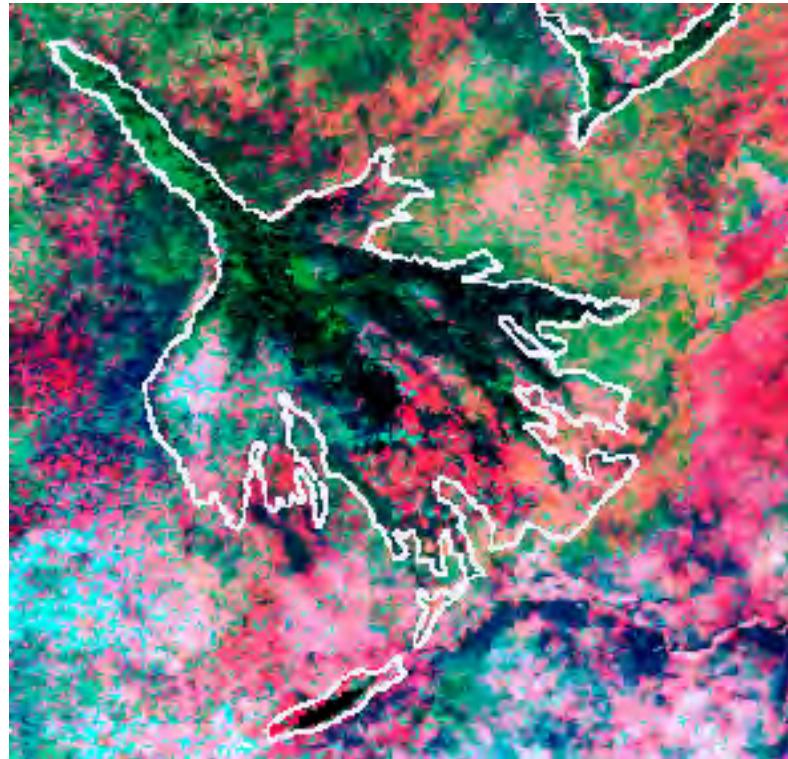
Blue = B1

Green = B2

Red = B3

(B = Band)

N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

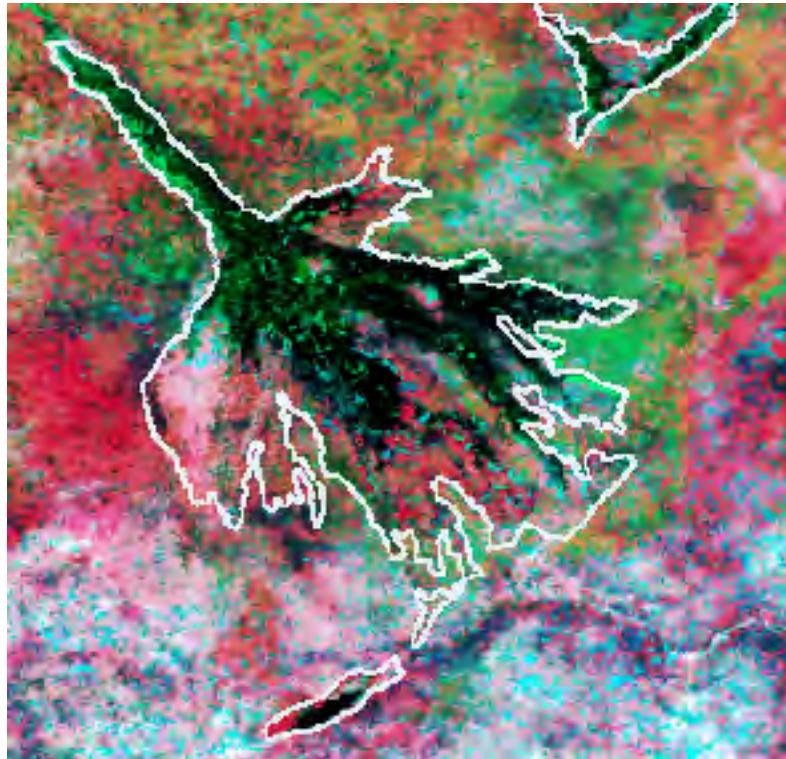
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

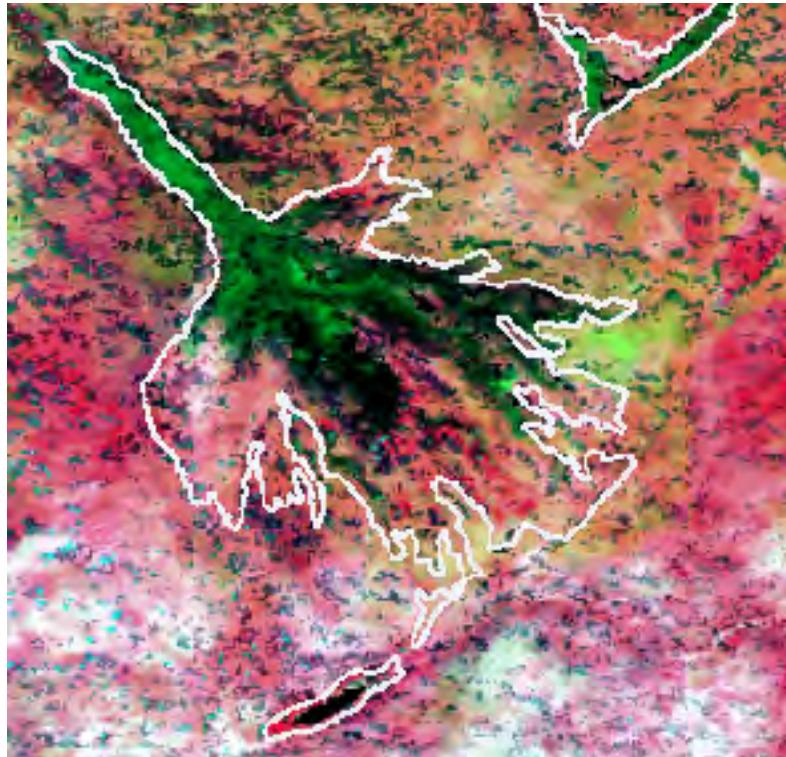
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

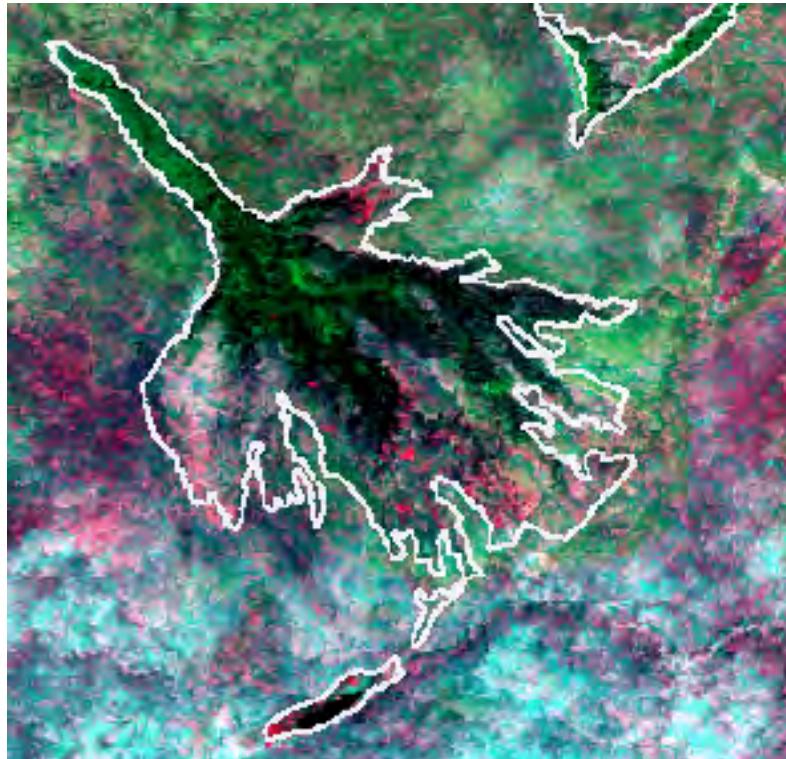
Blue = B1

Green = B2

Red = B3

(B = Band)

N



1993

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

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

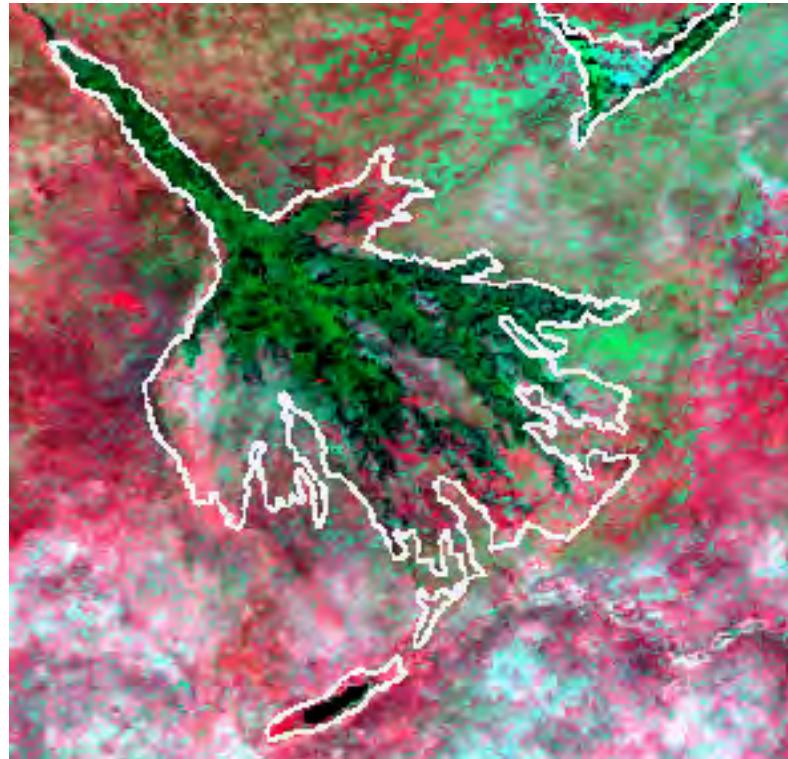
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

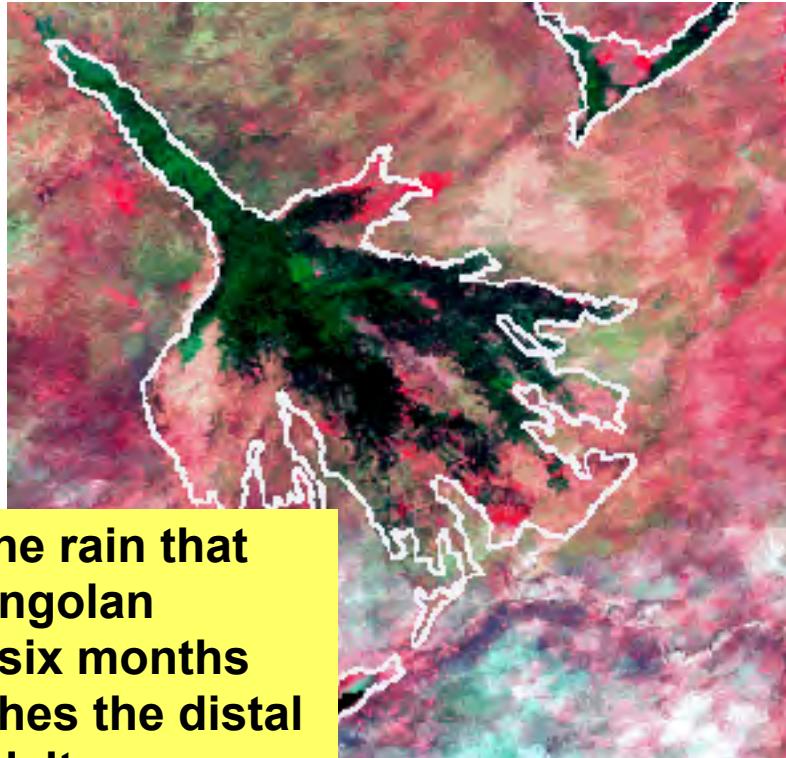
Image  
composition:

Blue = B1

Green = B2

Red = B3

(B = B<sub>1,2,3</sub>) **In August the rain that fell in the Angolan mountains six months earlier reaches the distal part of the delta**



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

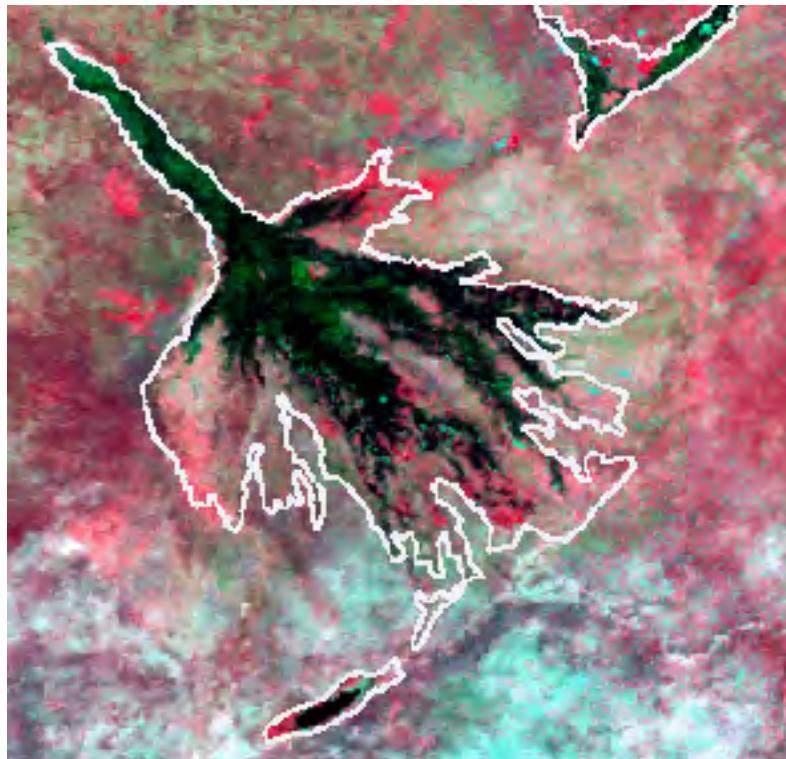
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

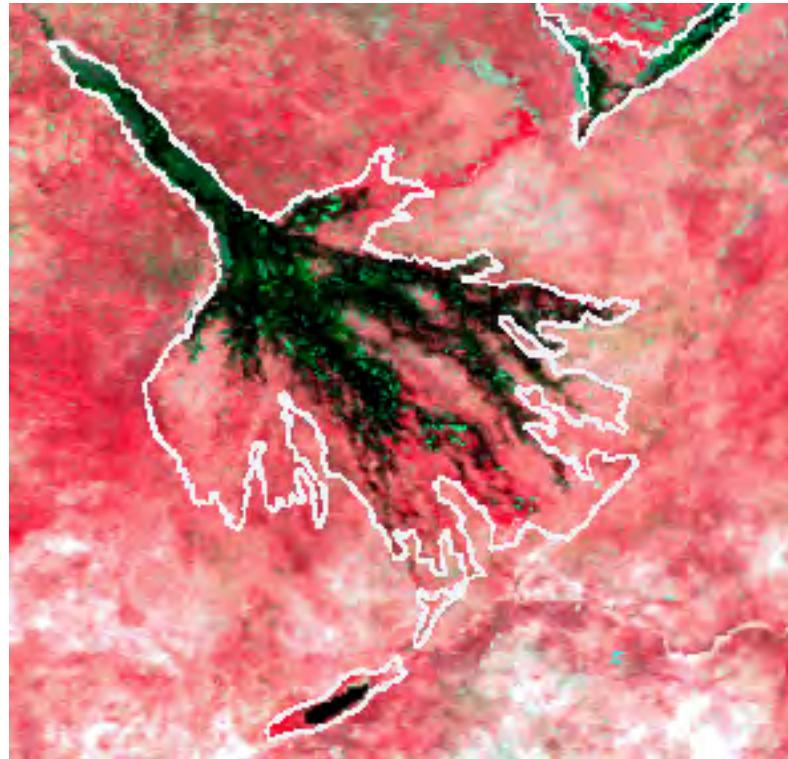
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

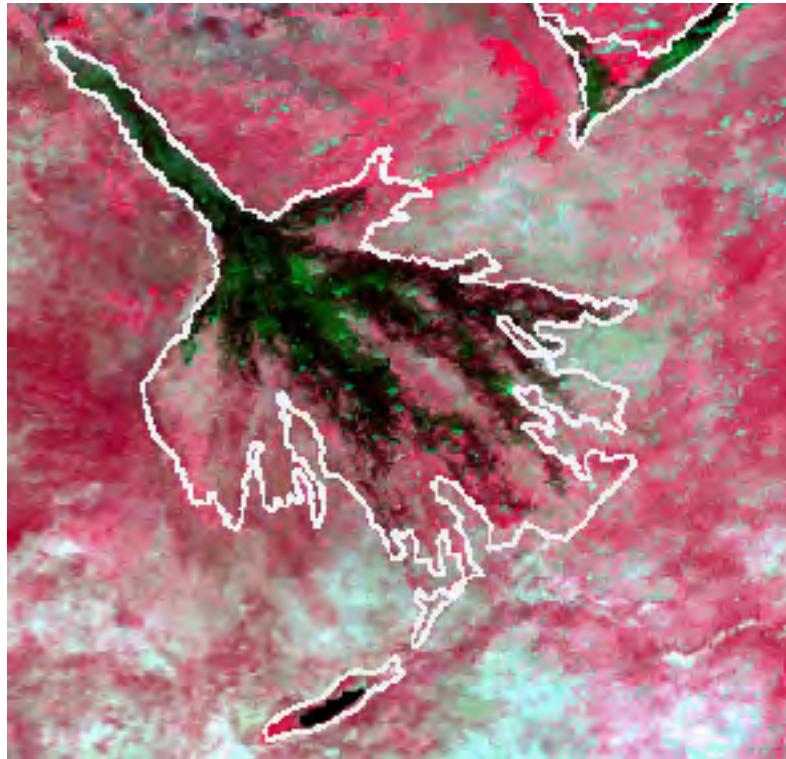
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

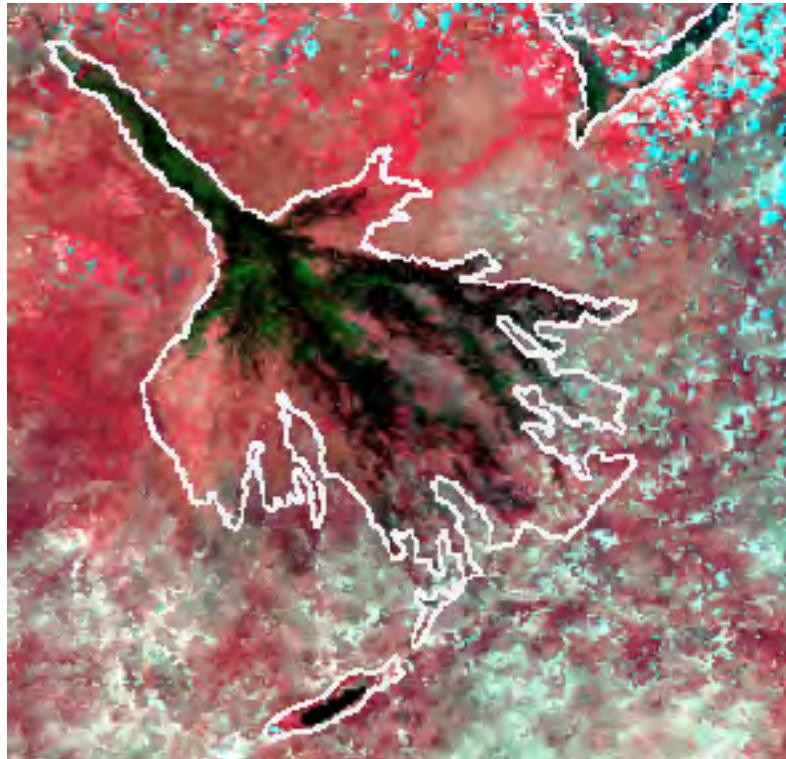
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



1993

Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

100 Km

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

# NOAA-AVHRR 10 day composite of the Okavango Delta

Image  
composition:

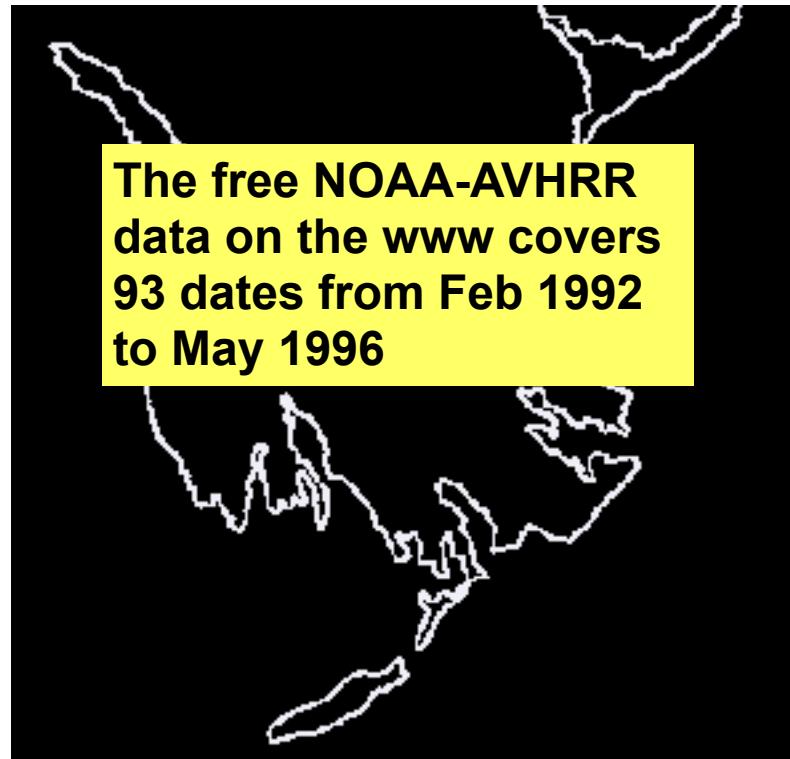
Blue = B1

Green = B2

Red = B3

(B = Band)

↑ N



Band  
wavelength:

B1 = Green

B2 = Near IR

B3 = IR

(IR = Infra Red)

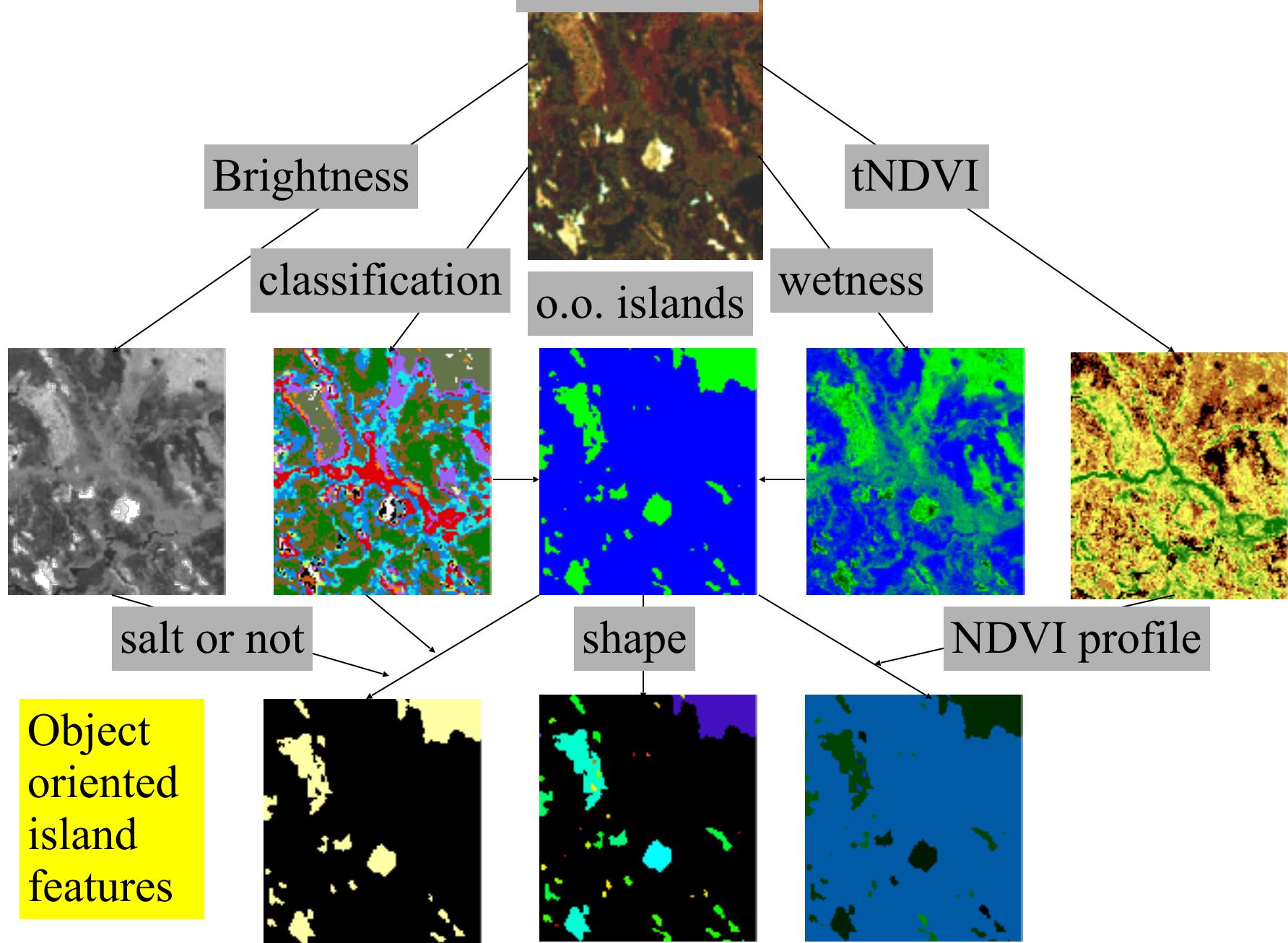
100 Km

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

# Data enhancement & interpretation



# Landsat TM



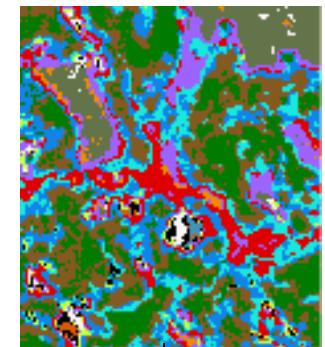
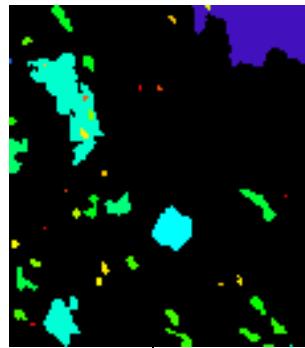
salt or not

shape

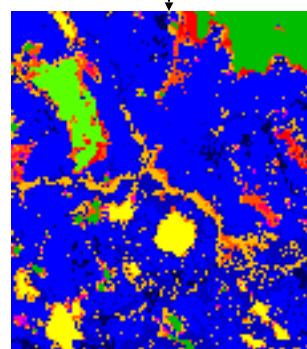
NDVI profile

classification

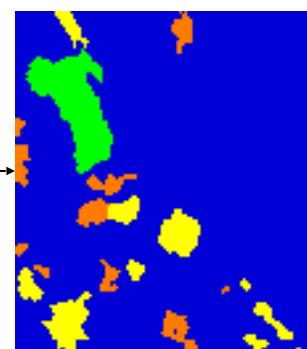
Object  
oriented  
island  
features



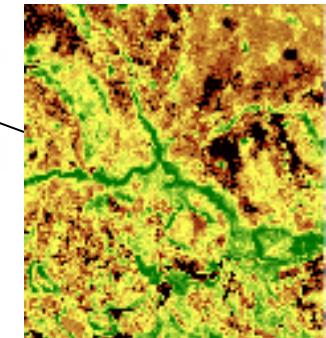
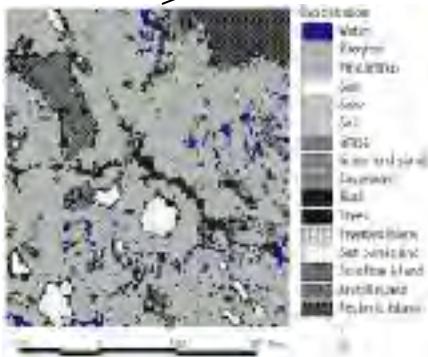
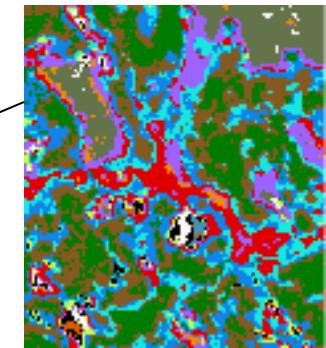
Rule based (if .... then ....) classification



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:

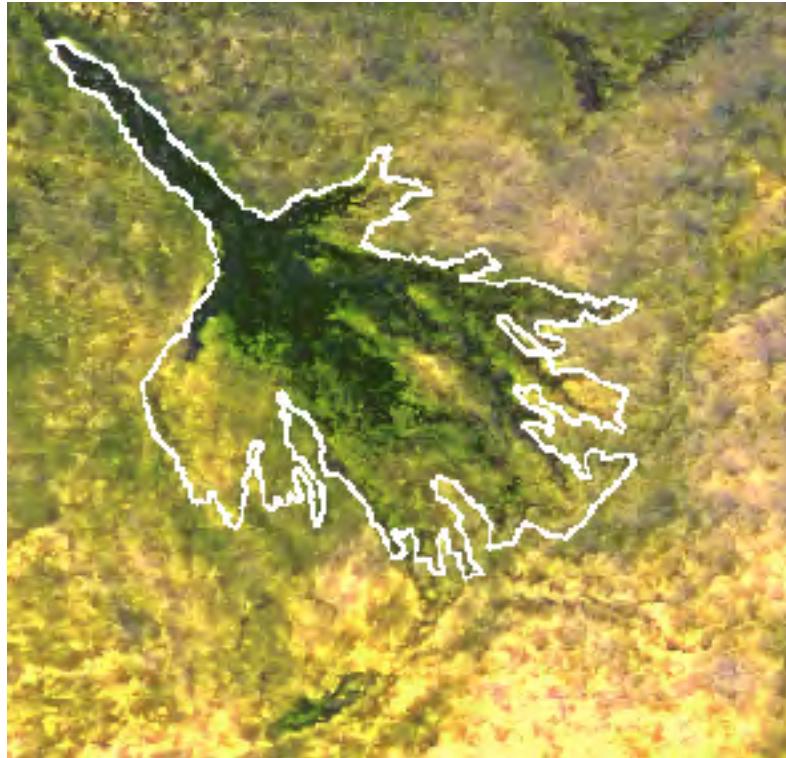
Blue = B1

Green = B1+B3

Red = B2

(B = Band)

↑ N



1992

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

Band  
wavelength:

B1 = Green

B2 = Near IR

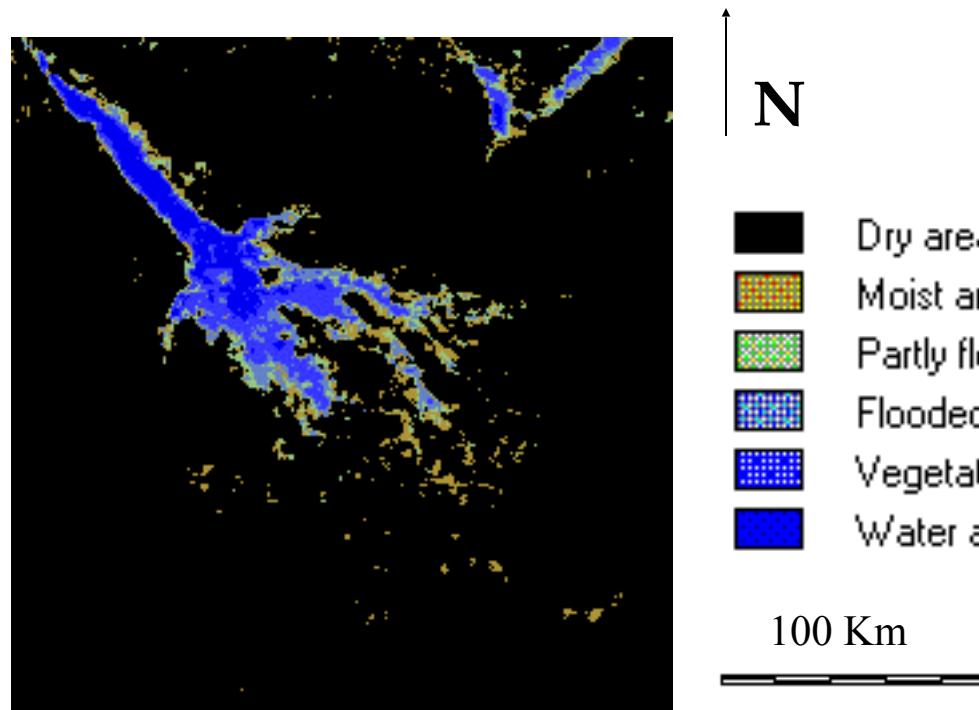
B3 = IR

(IR = Infra Red)

100 Km

NOAA-AVHRR 10 day composite derived water mask

## Okavango Delta

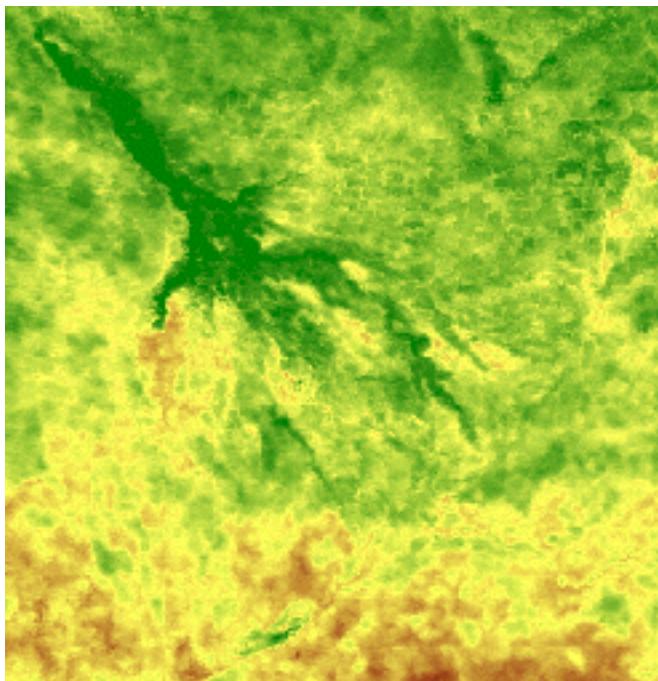
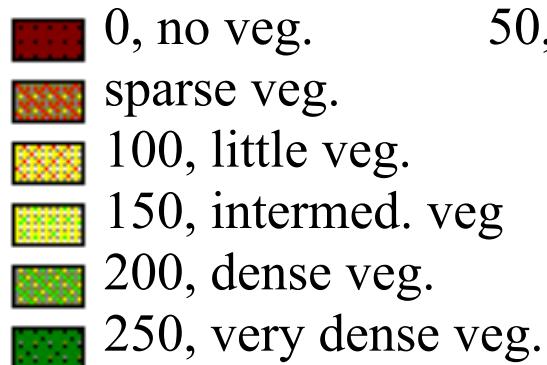


1992

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

# NOAA-AVHRR 10 day composite NDVI

## Okavango Delta



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

$$\begin{aligned}\text{NIR} &= \text{band 2} \\ \text{VIS} &= \text{band 1}\end{aligned}$$

Precipitation in  
Maun (mm)



# Okavango Delta, Botswana



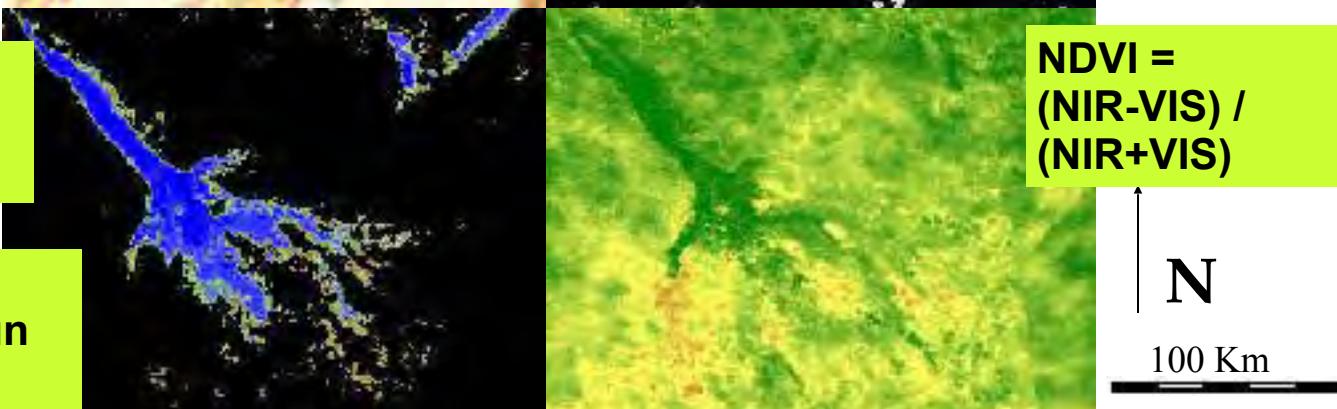
Colour composite  
Blue = B1  
Green = B1+B3  
Red = B2



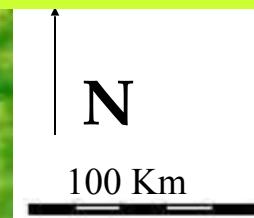
Cloud  
thresholding  
from TIR bands



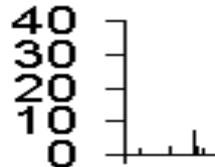
Precipitation –  
average of Maun  
and Shakawe



$$\text{NDVI} = \frac{(\text{NIR}-\text{VIS})}{(\text{NIR}+\text{VIS})}$$



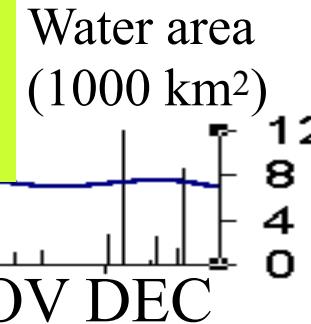
Precipitation  
(mm)



1992

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

Water area as  
weighted mean  
of three 10-day  
composites



# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

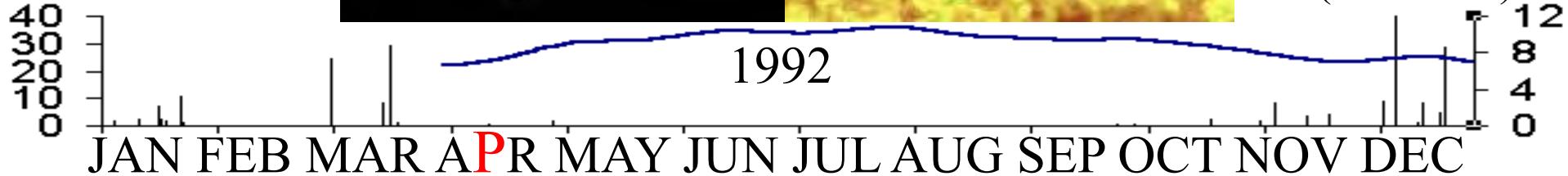
True  
colours



Water



Precipitation  
(mm)



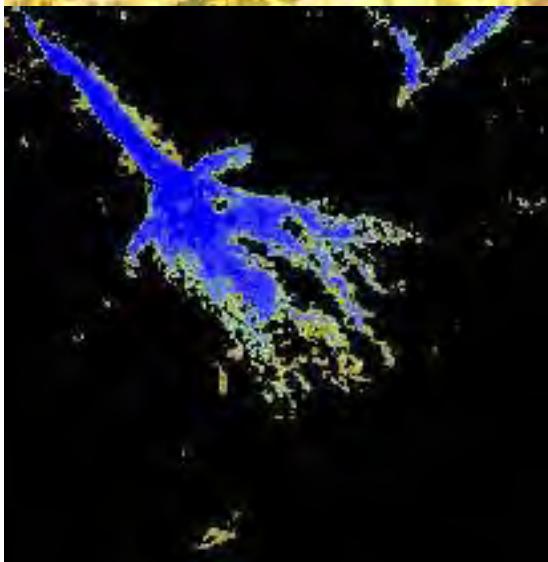
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

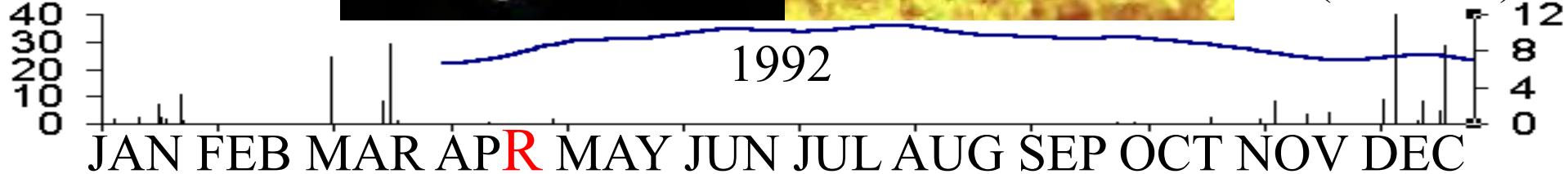
True  
colours



Water



Precipitation  
(mm)



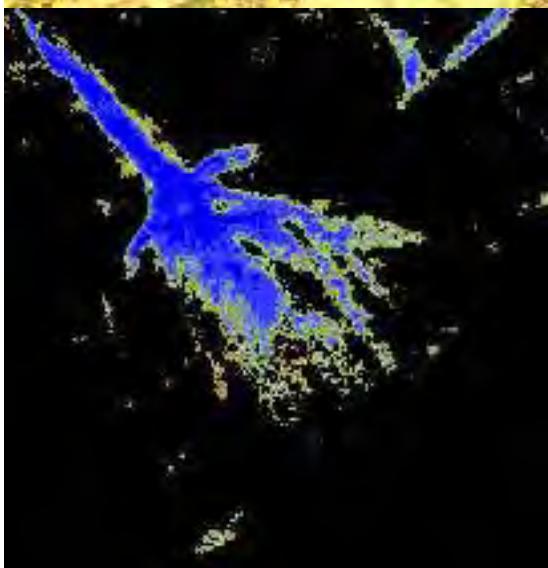
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

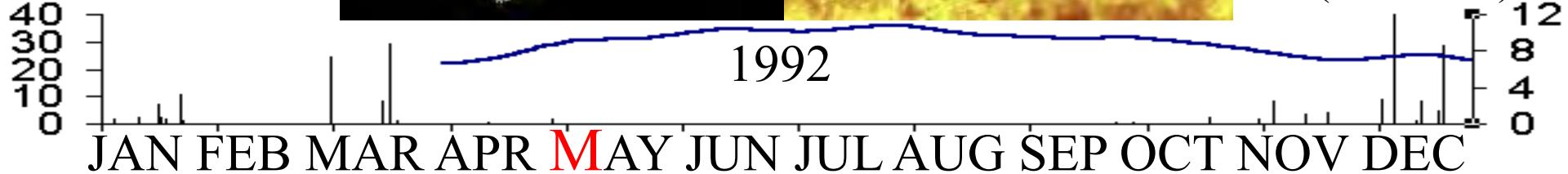
True  
colours



Water



Precipitation  
(mm)



# Okavango Delta, Botswana

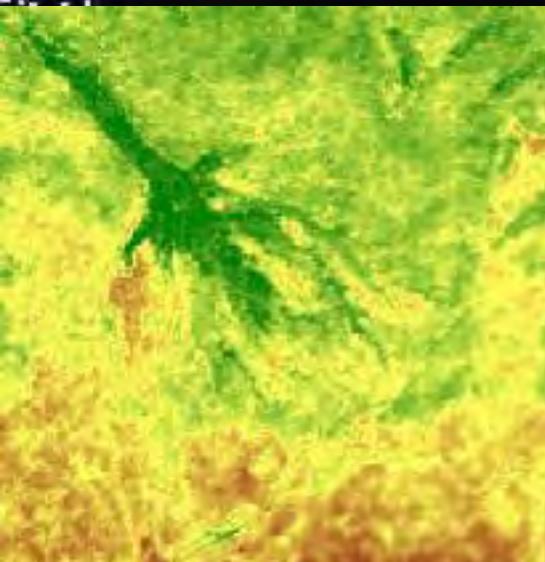
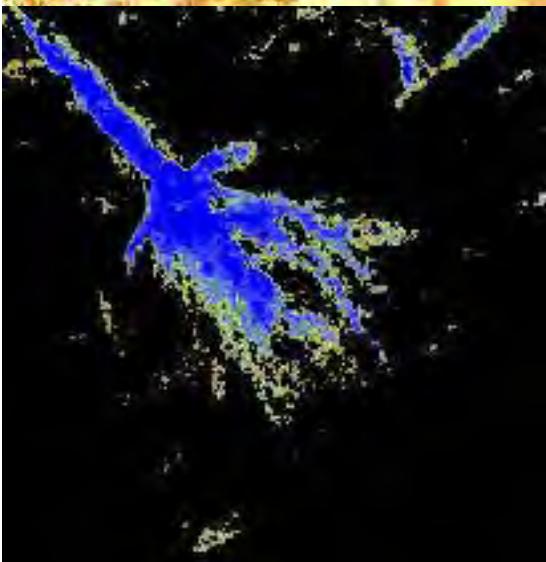
NOAA-  
AVHRR  
Images

True  
colours



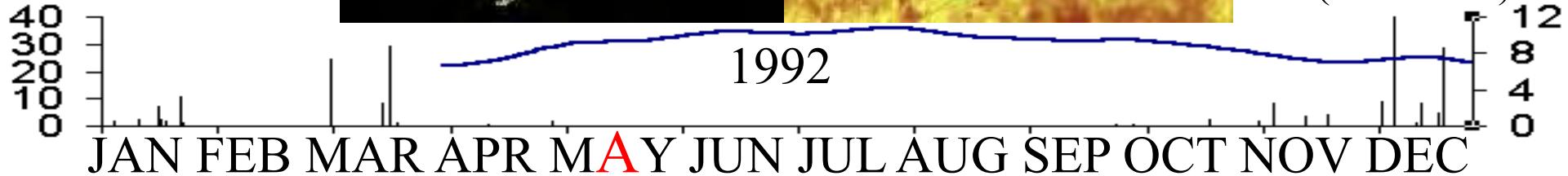
Clouds

Water



NDVI

Precipitation  
(mm)



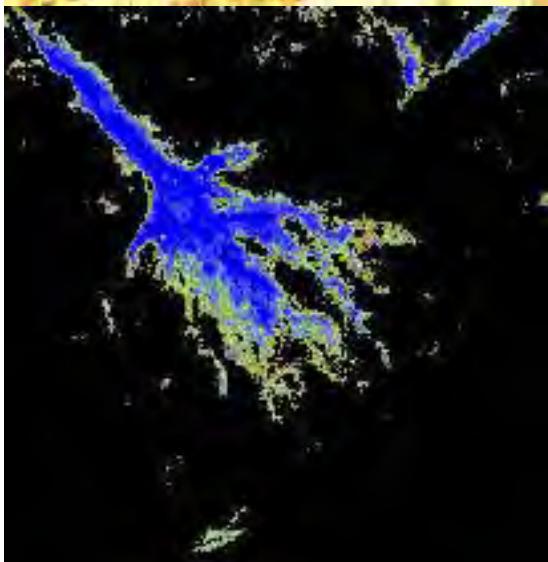
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)

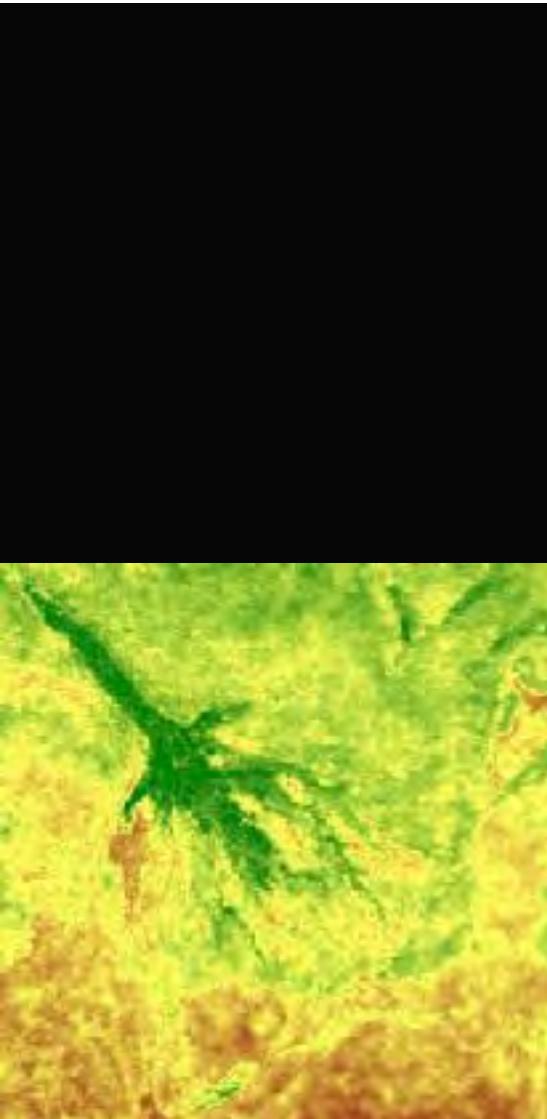


Clouds

NDVI

N

100 Km



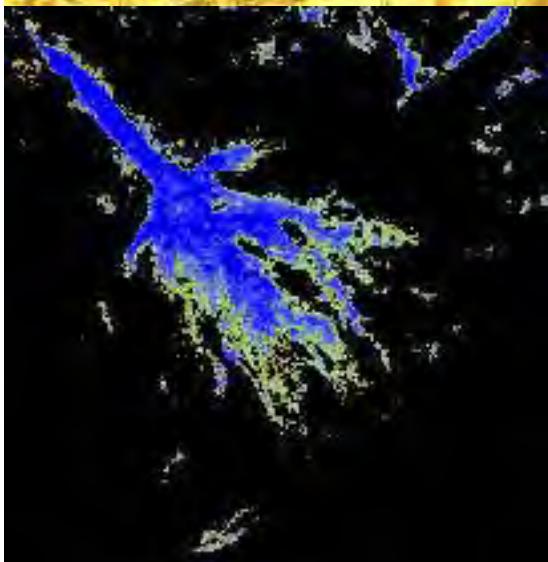
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

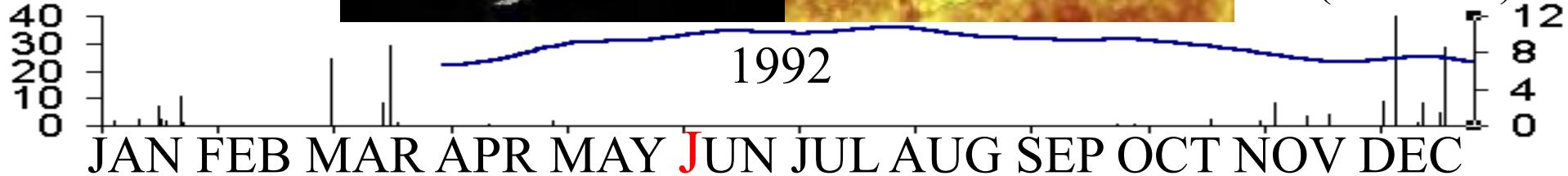
True  
colours



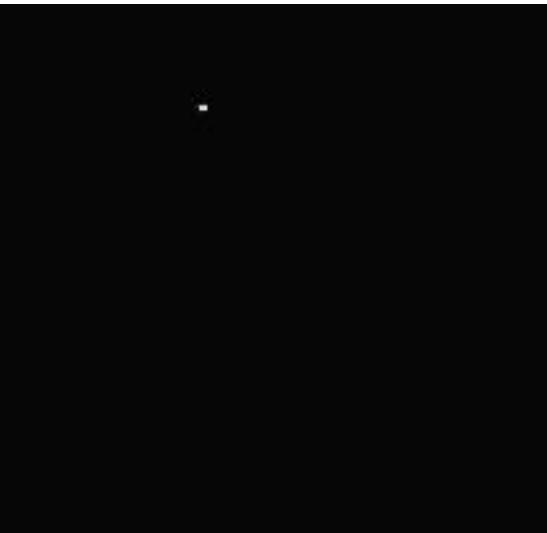
Water



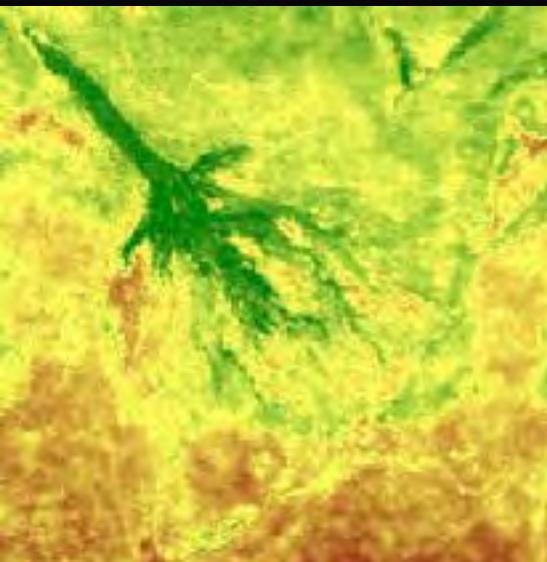
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
( $1000 \text{ km}^2$ )

12  
8  
4  
0

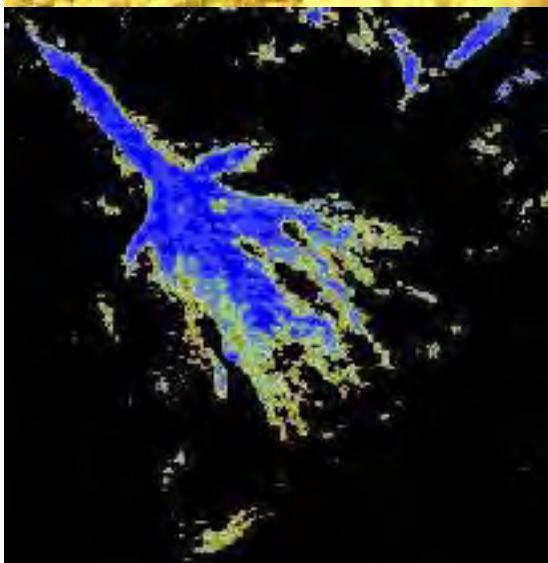
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



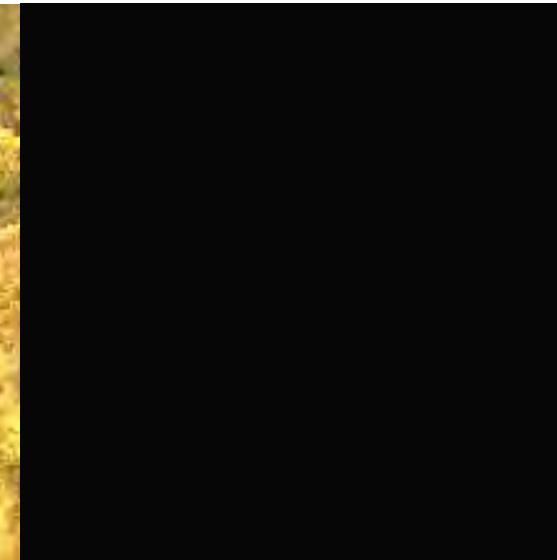
Water



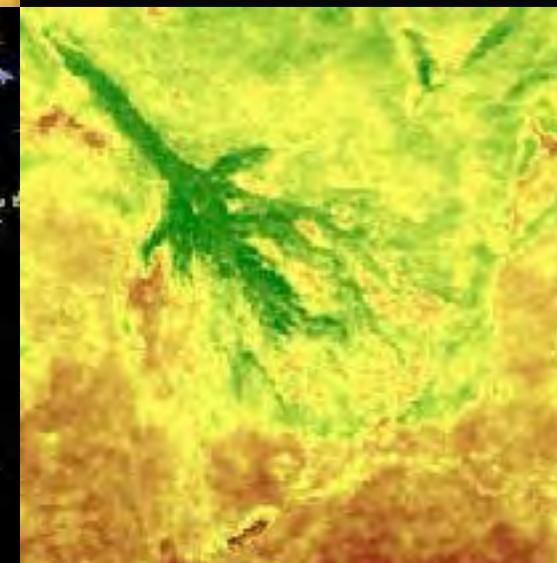
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
(1000 km<sup>2</sup>)

12  
8  
4  
0

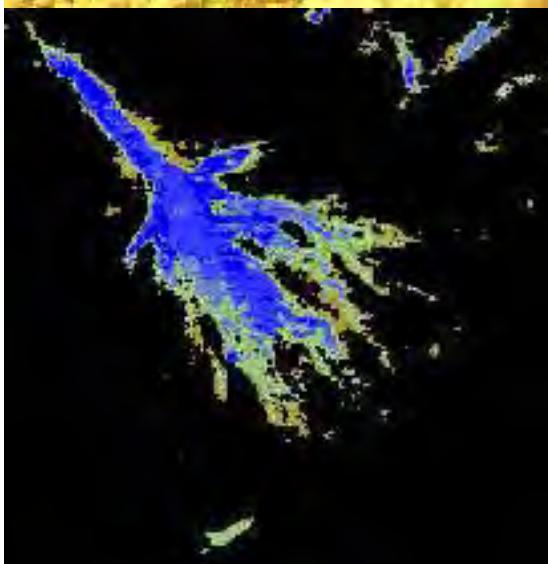
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



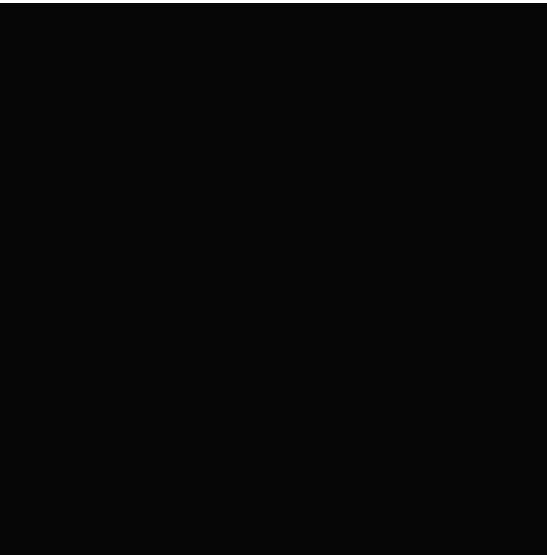
Water



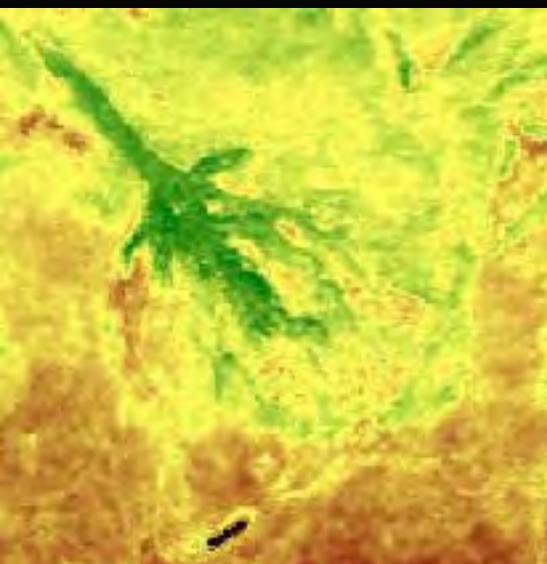
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
(1000 km<sup>2</sup>)

12  
8  
4  
0

1992

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

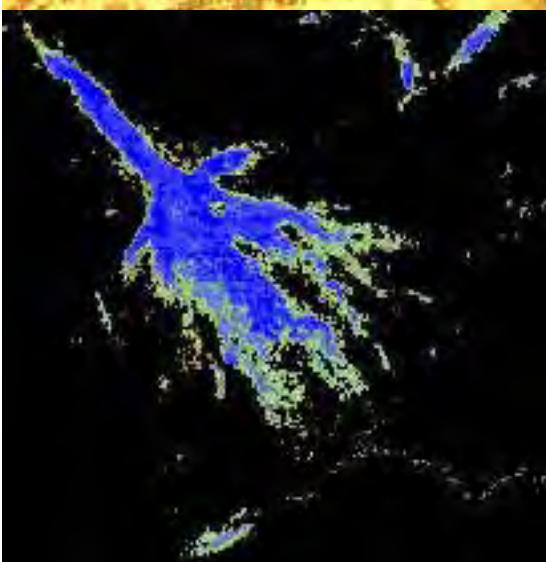
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



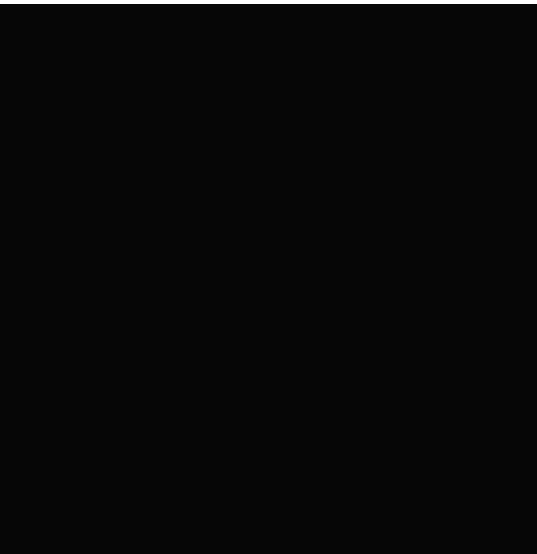
Water



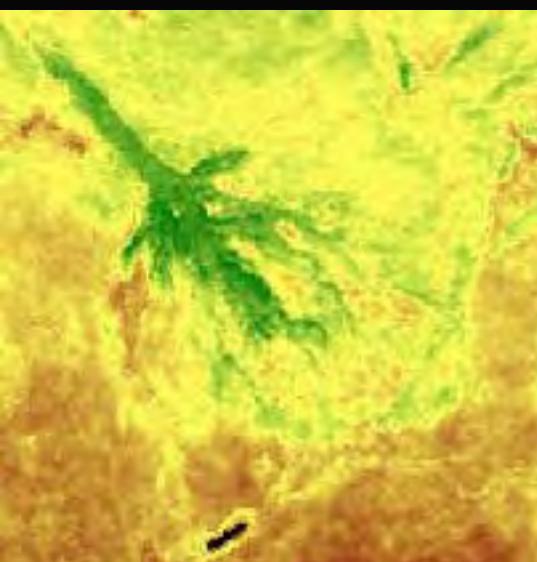
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
(1000 km<sup>2</sup>)



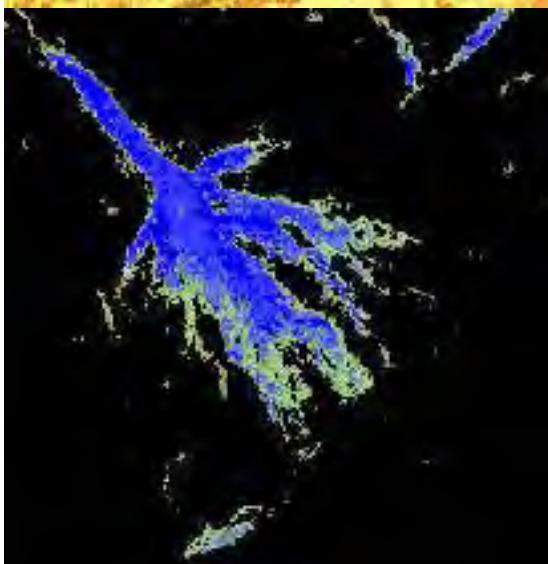
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

N

100 Km

Water area  
(1000 km²)

12  
8  
4  
0

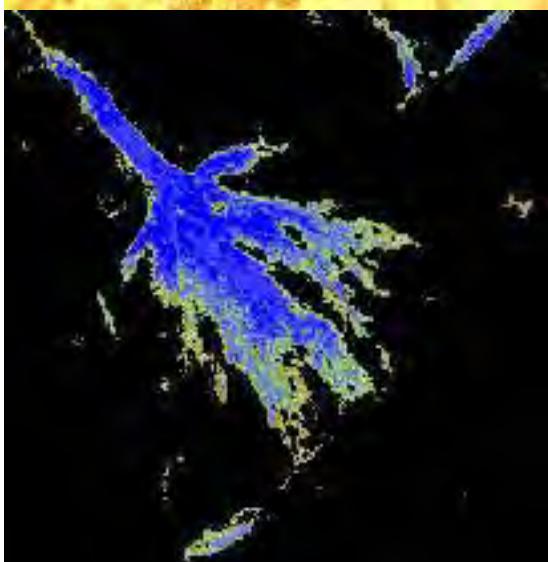
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)



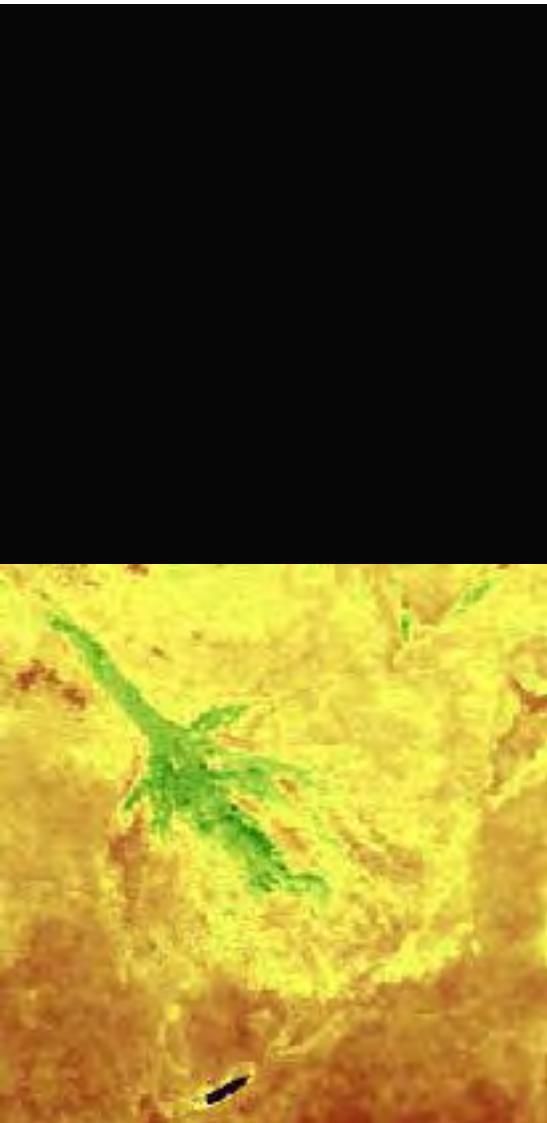
Clouds

NDVI

N

100 Km

Water area  
(1000 km²)

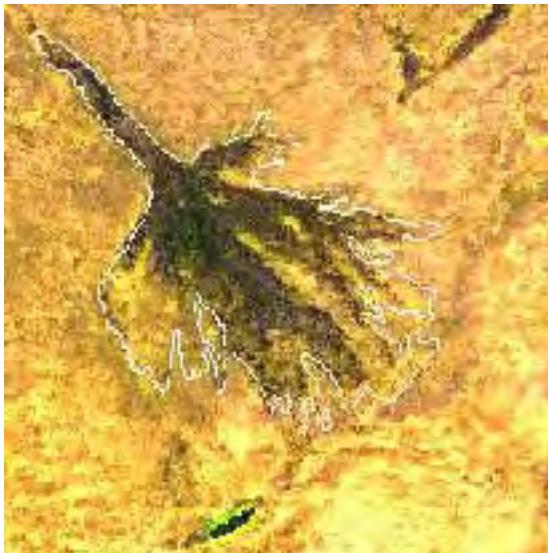


1992

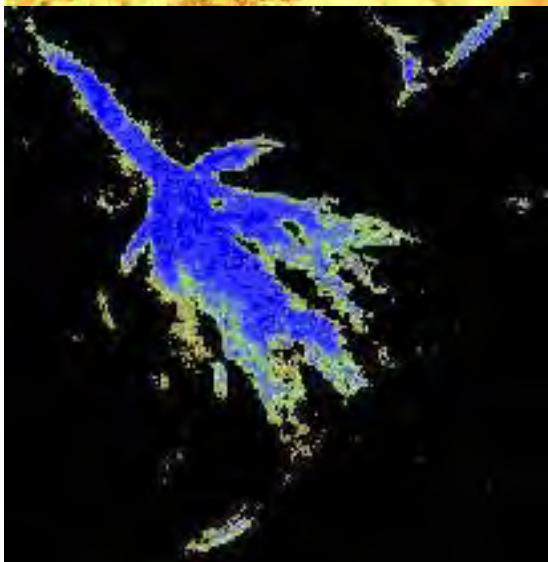
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)



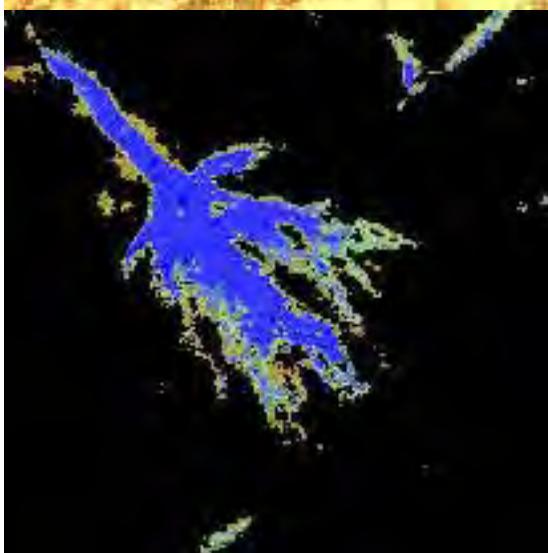
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)



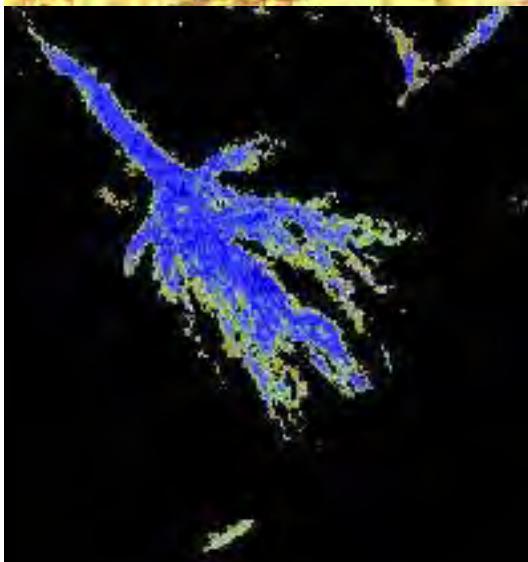
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



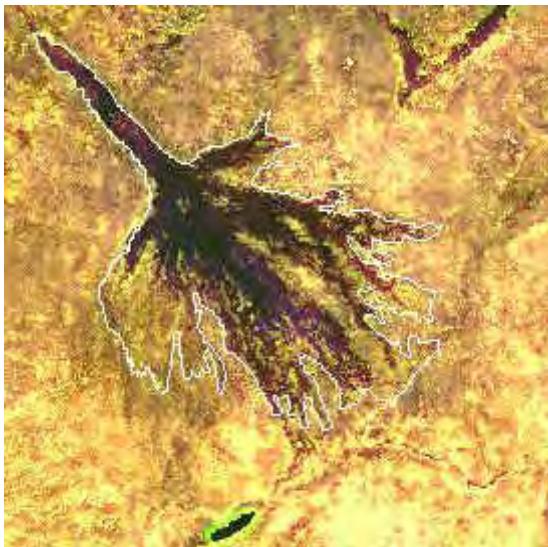
Precipitation  
(mm)



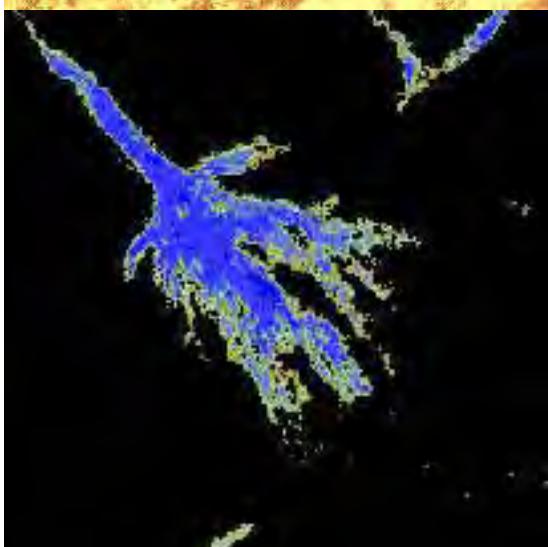
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

N

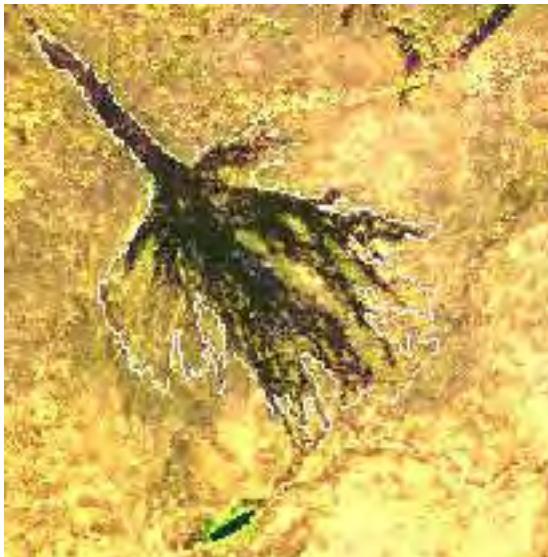
100 Km

Water area  
(1000 km<sup>2</sup>)

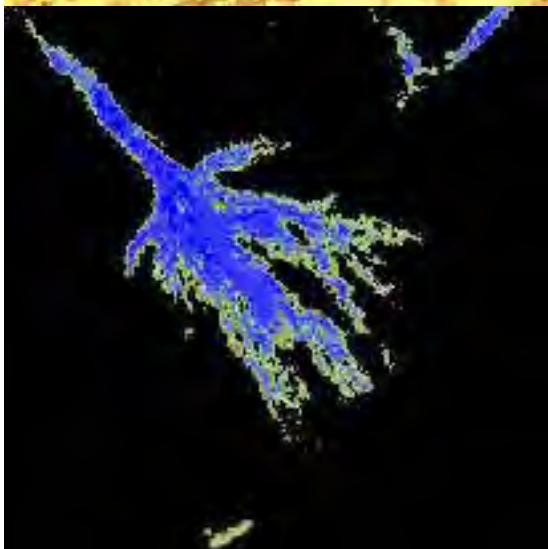
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



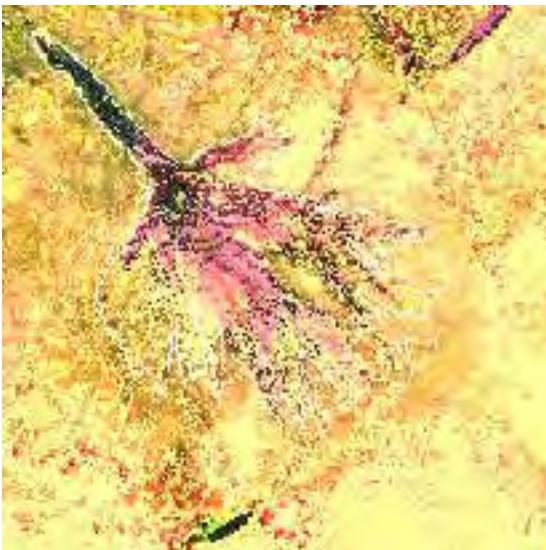
Precipitation  
(mm)



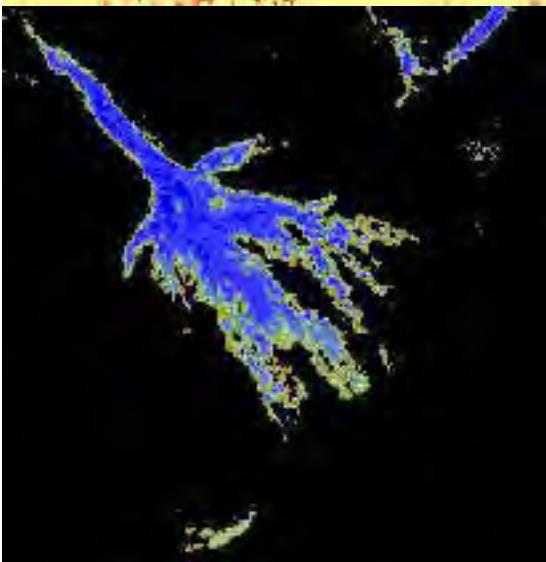
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

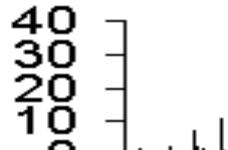
True  
colours



Water



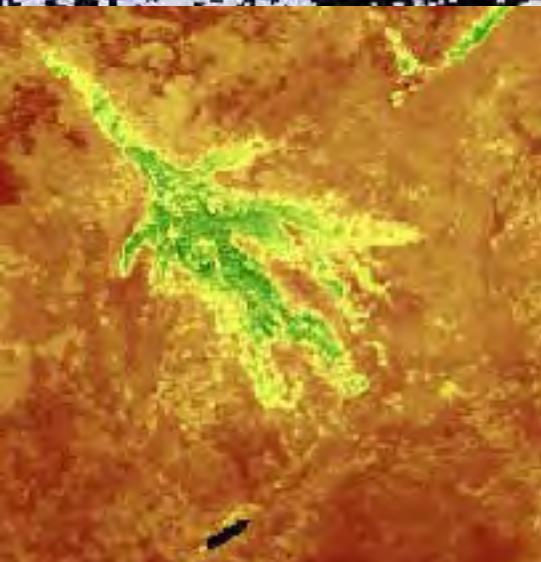
Precipitation  
(mm)



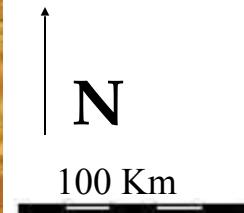
1992



Clouds



NDVI



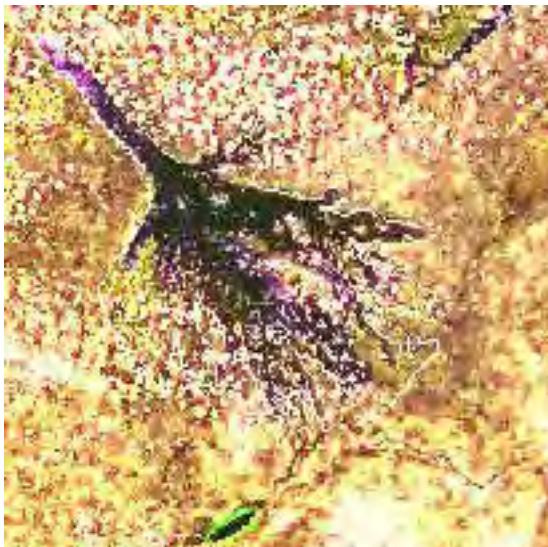
Water area  
(1000 km<sup>2</sup>)



# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

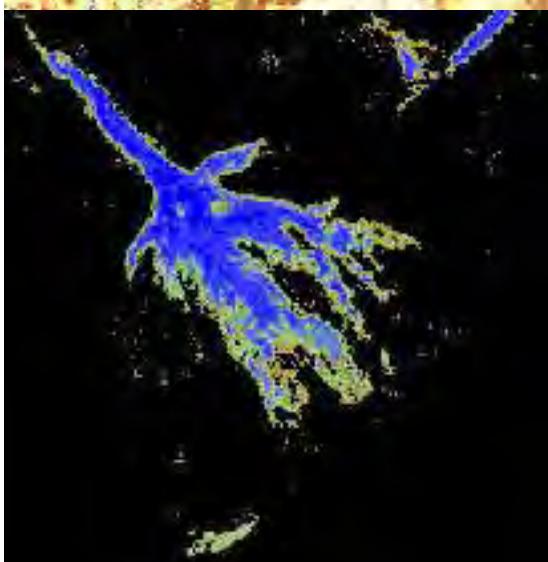
True  
colours



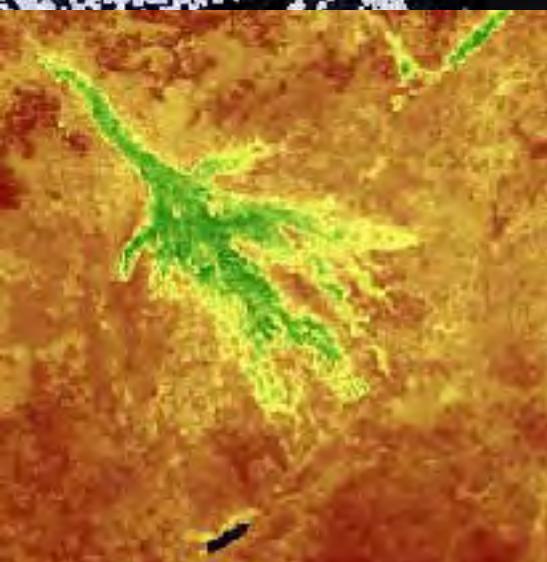
Clouds



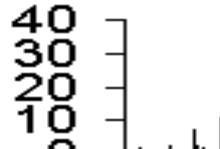
Water



NDVI

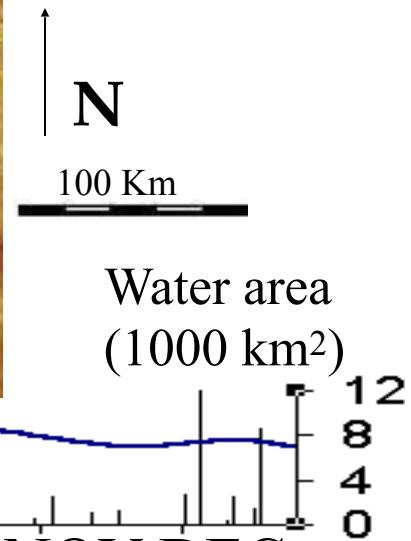


Precipitation  
(mm)



1992

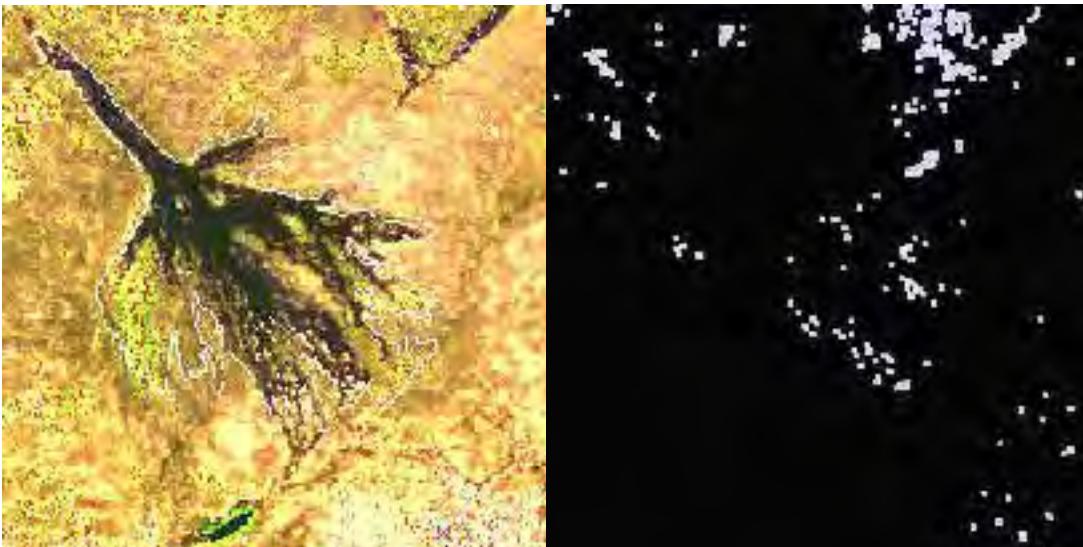
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC



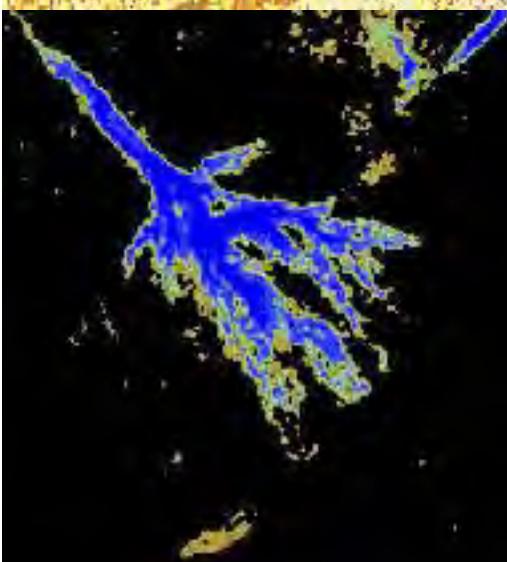
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



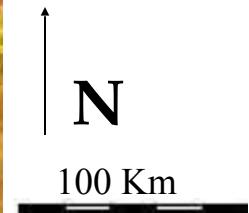
Water



Precipitation  
(mm)



Clouds  
NDVI

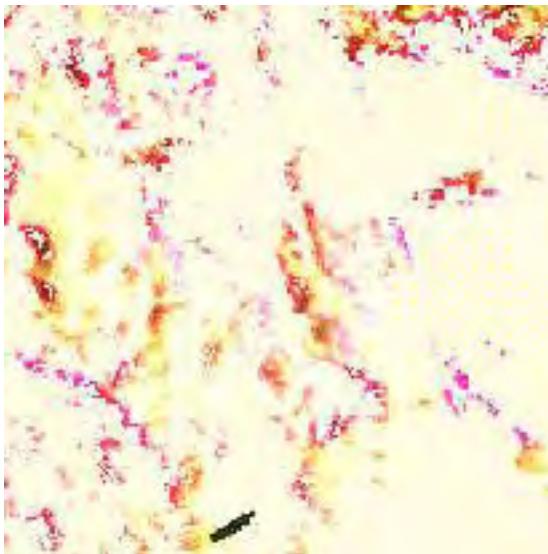


Water area  
(1000 km²)

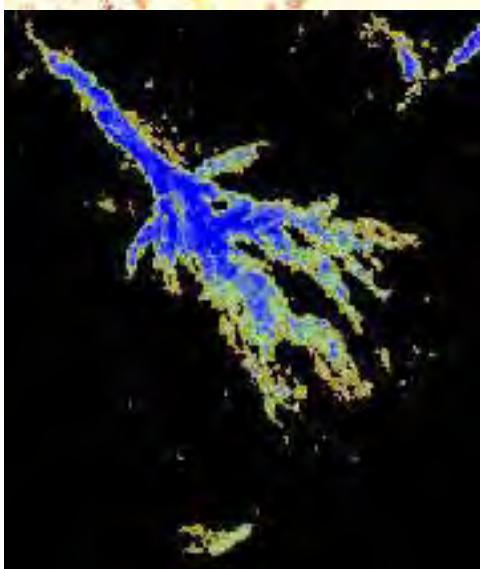
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



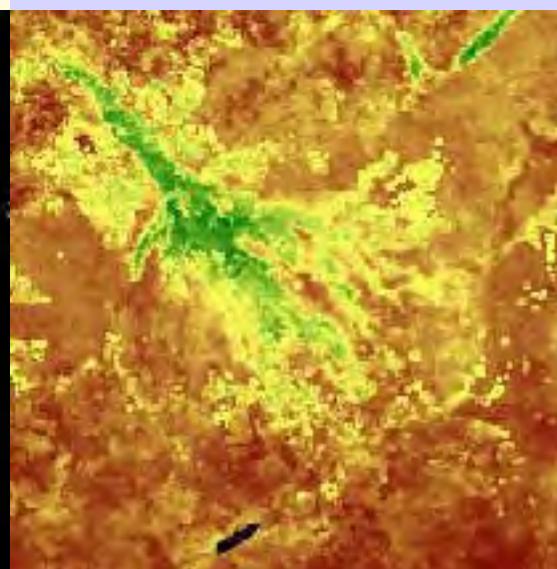
Water



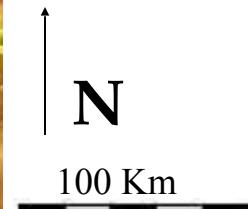
Precipitation  
(mm)



Clouds



NDVI



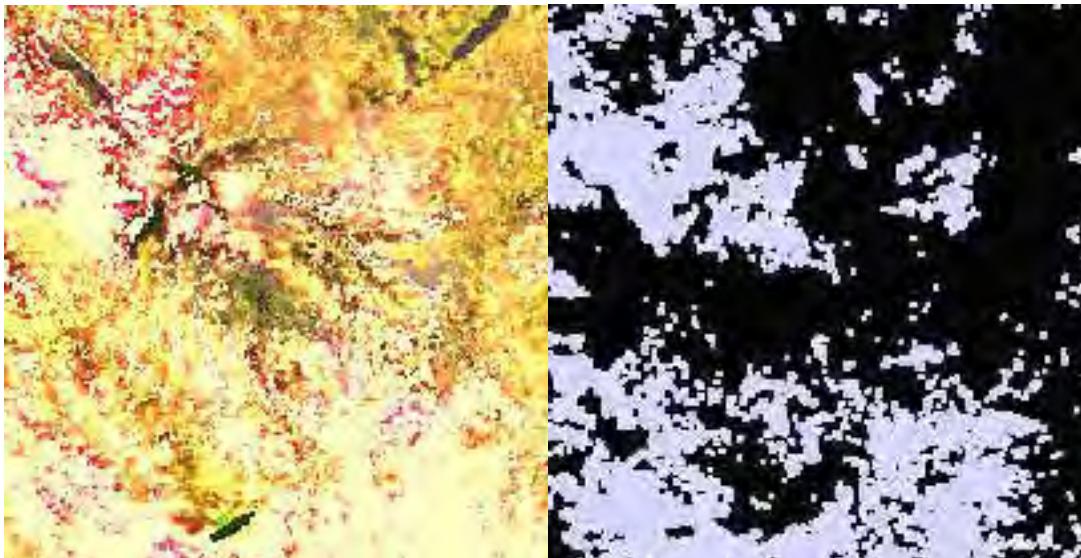
Water area  
(1000 km<sup>2</sup>)



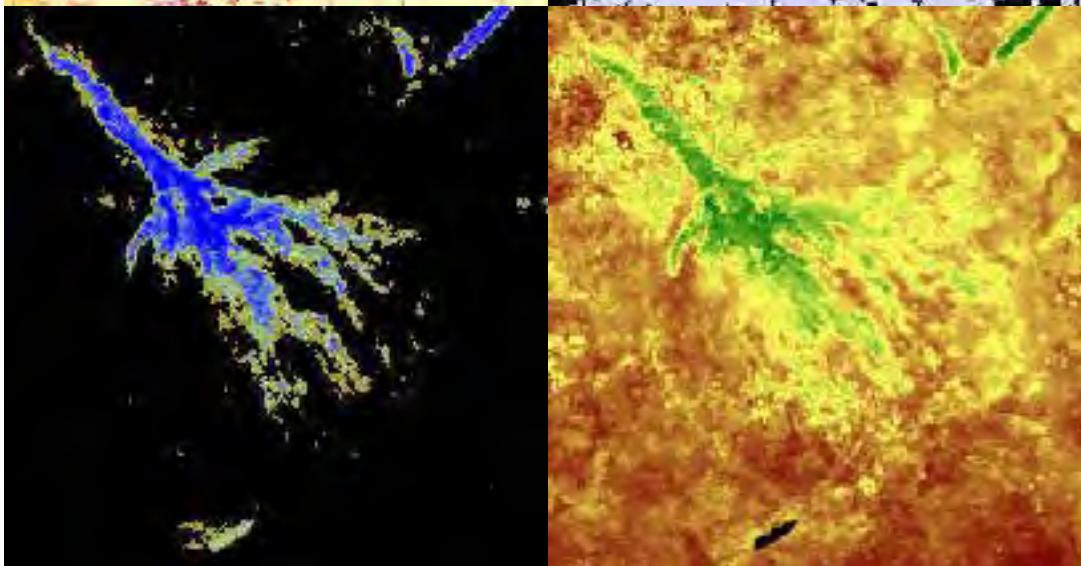
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water

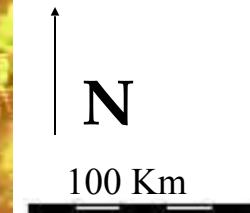


Precipitation  
(mm)



Clouds

NDVI



Water area  
(1000 km<sup>2</sup>)

12  
8  
4  
0

1992

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

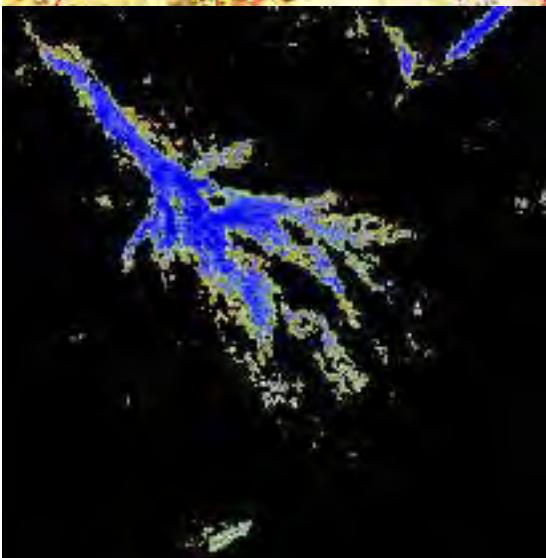
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

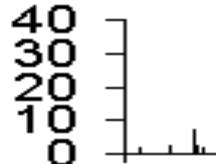
True  
colours



Water



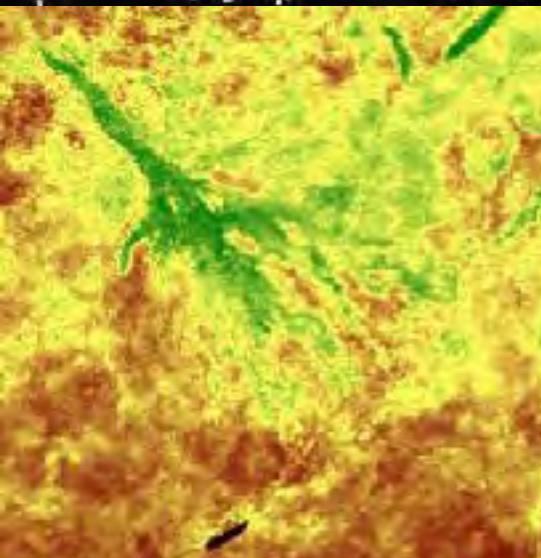
Precipitation  
(mm)



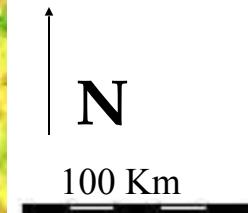
1992



Clouds



NDVI



Water area  
(1000 km<sup>2</sup>)

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



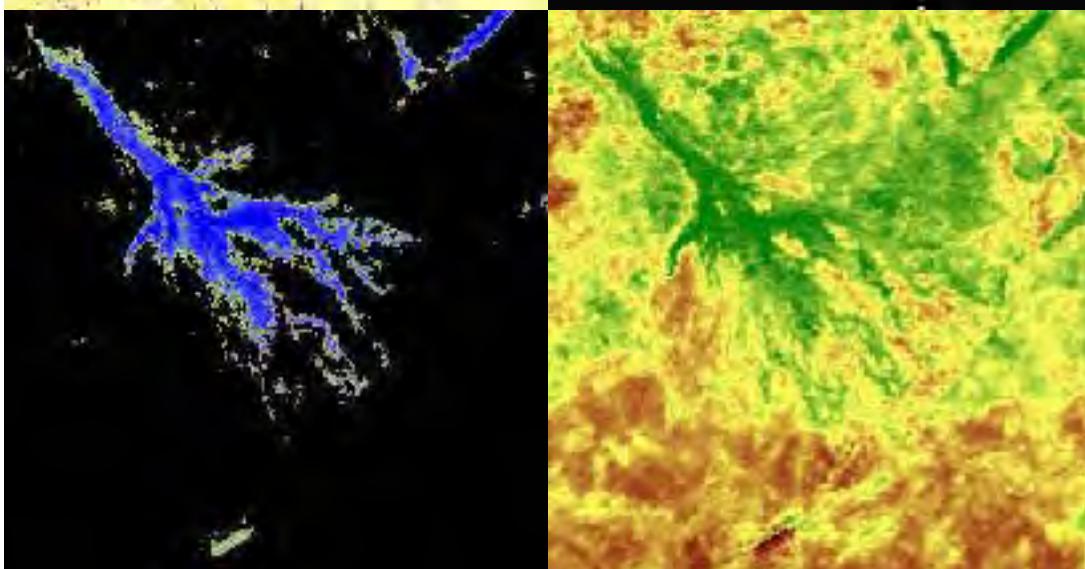
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



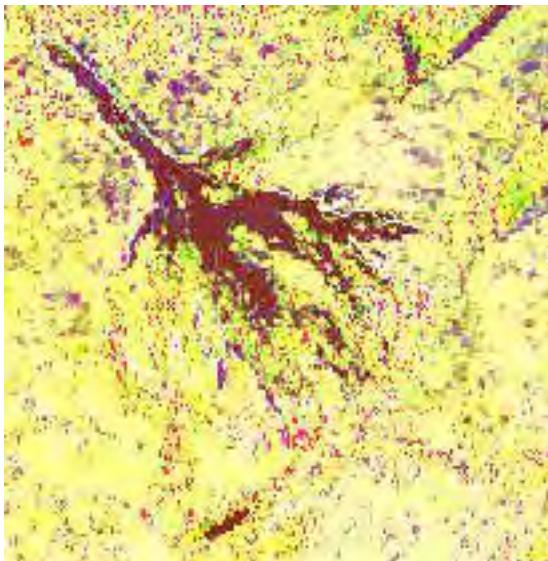
Precipitation  
(mm)



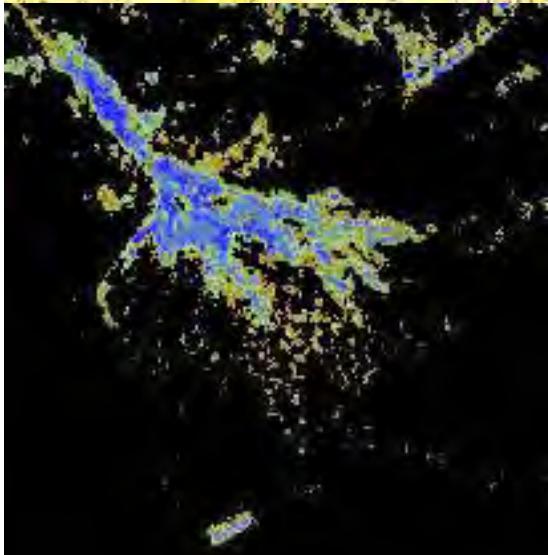
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



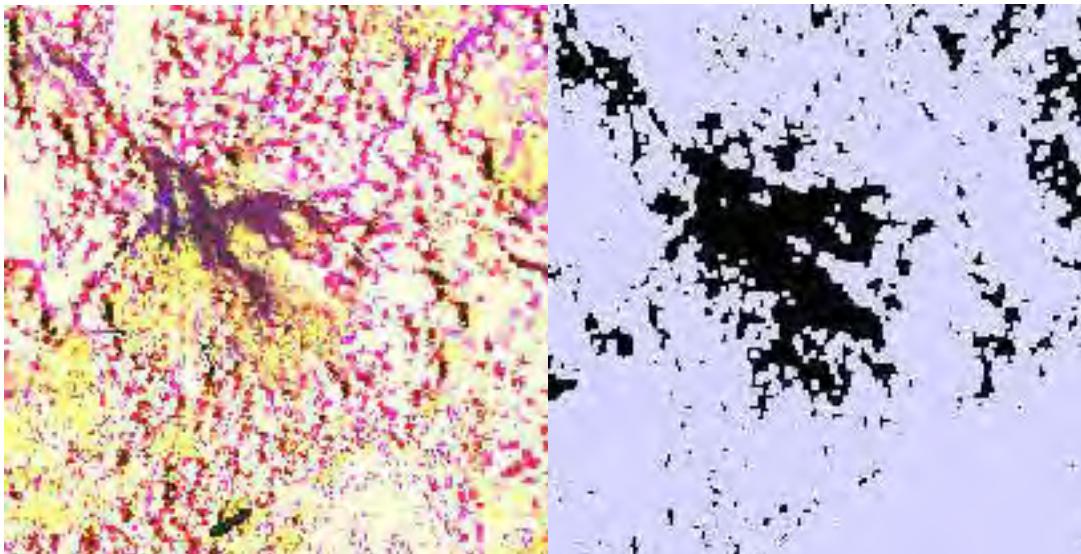
Precipitation  
(mm)



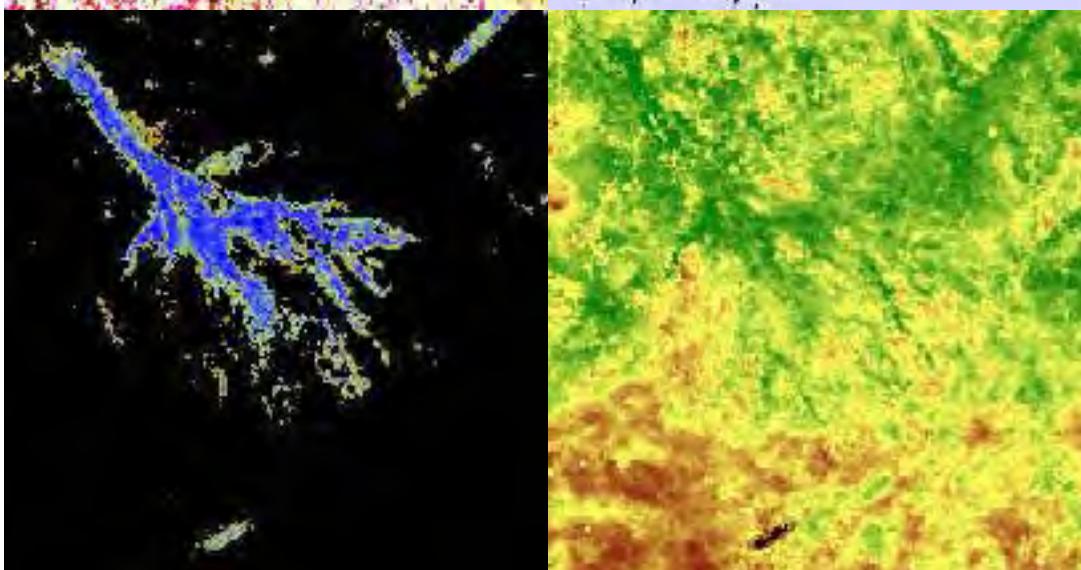
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

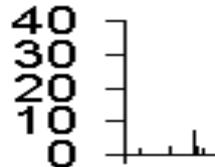
True  
colours



Water



Precipitation  
(mm)

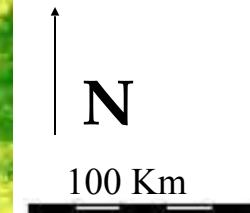


JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

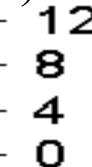
1992

Clouds

NDVI



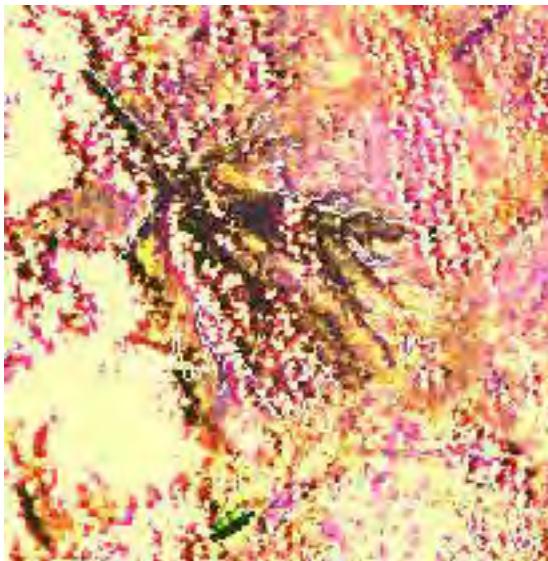
Water area  
(1000 km<sup>2</sup>)



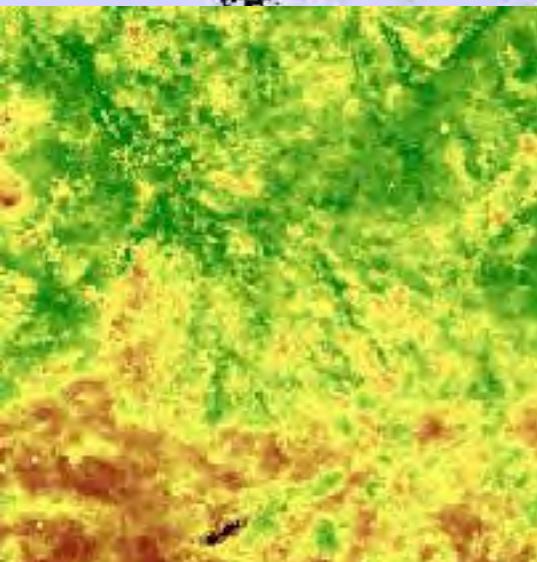
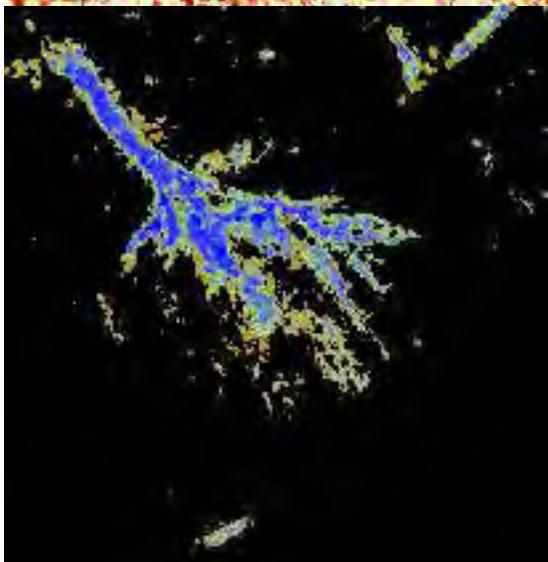
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water



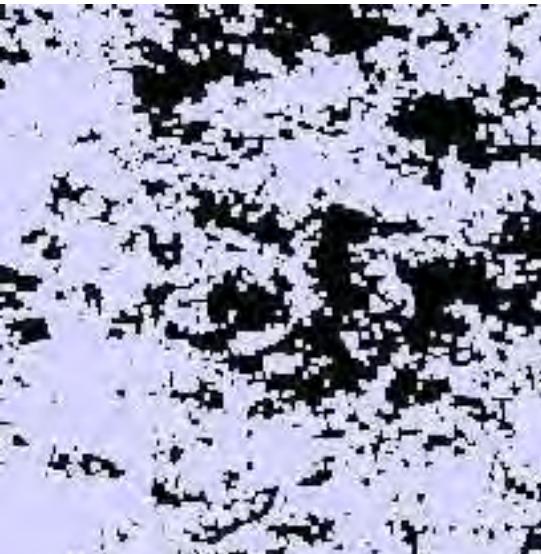
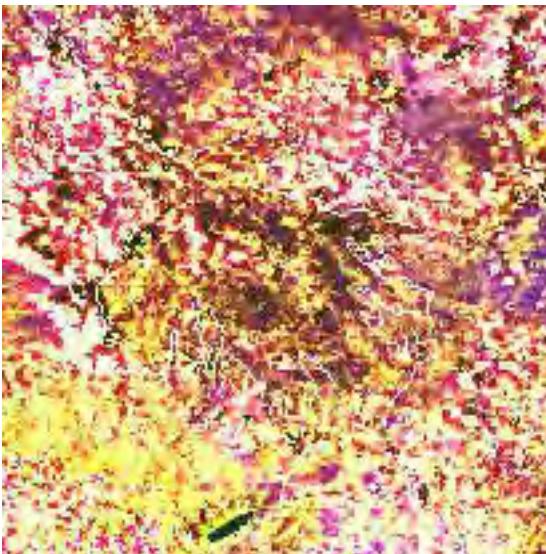
Precipitation  
(mm)



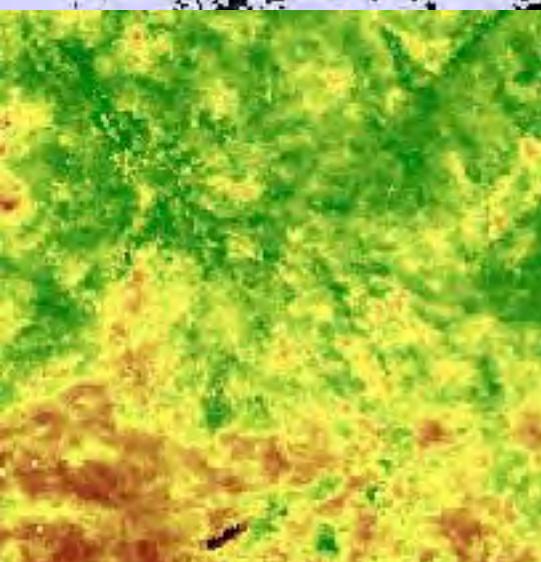
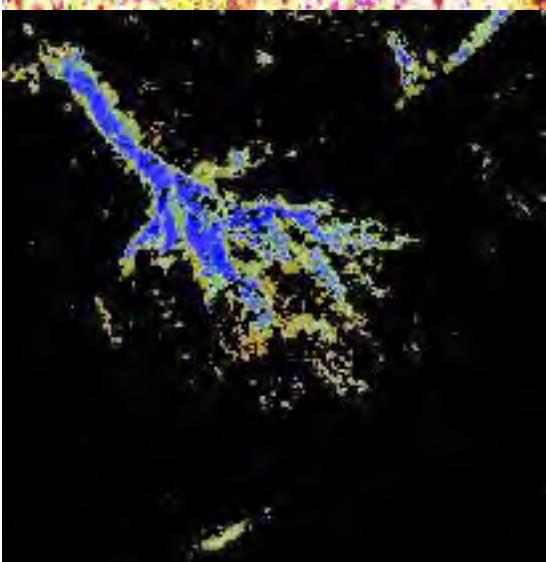
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

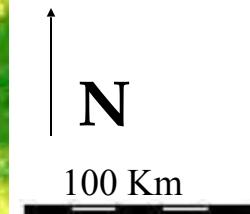
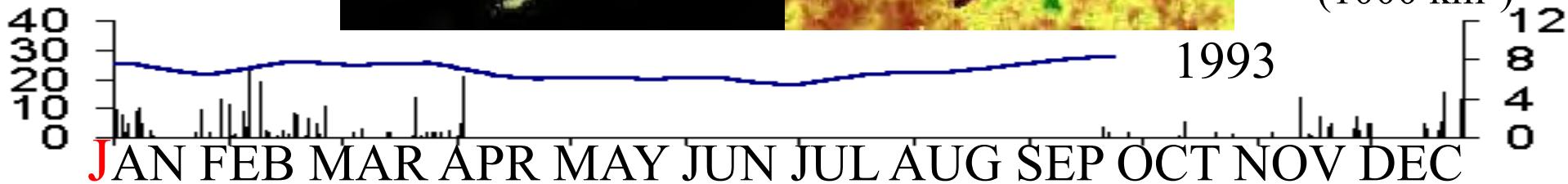
True  
colours



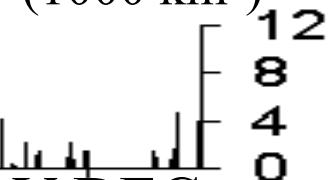
Water



Precipitation  
(mm)



Water area  
(1000 km<sup>2</sup>)



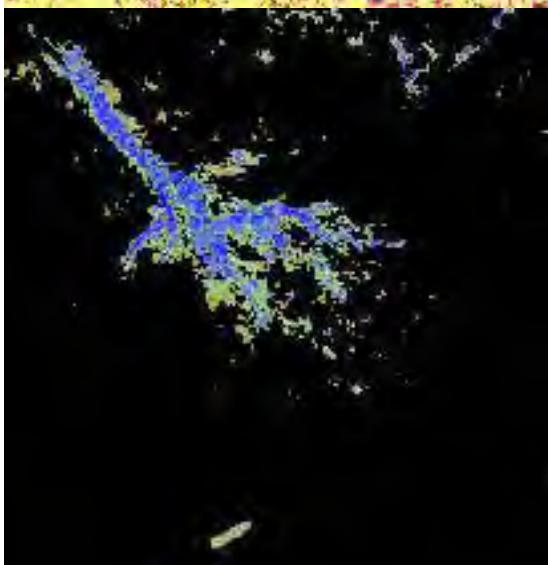
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

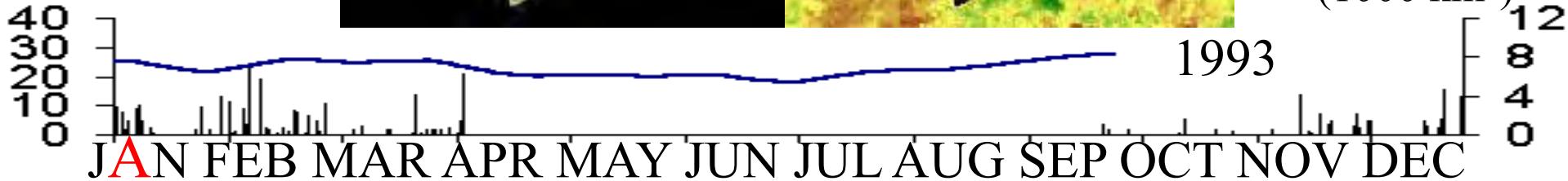
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

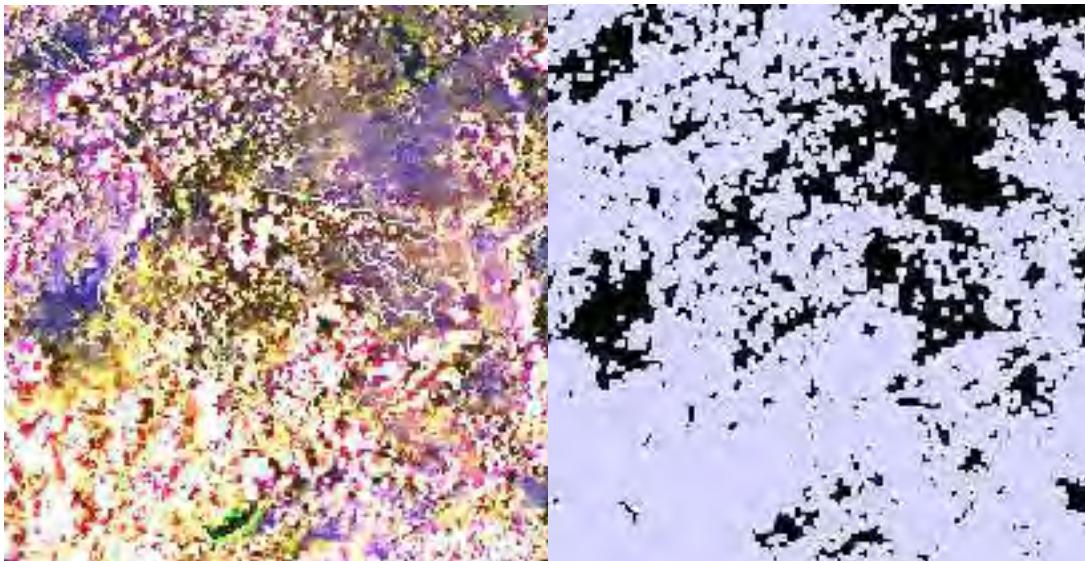
N  
100 Km

Water area  
(1000 km<sup>2</sup>)

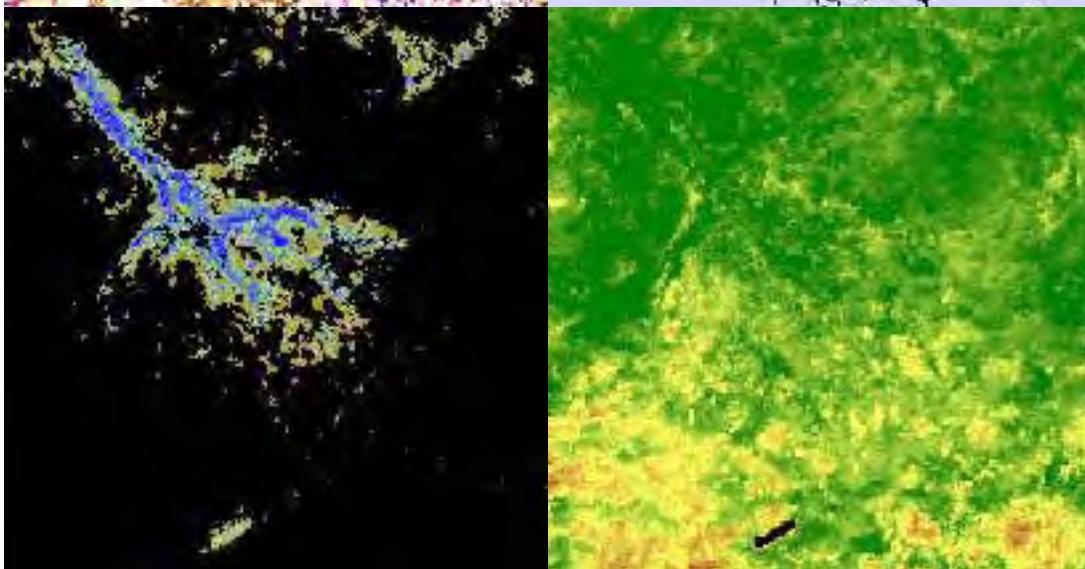
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

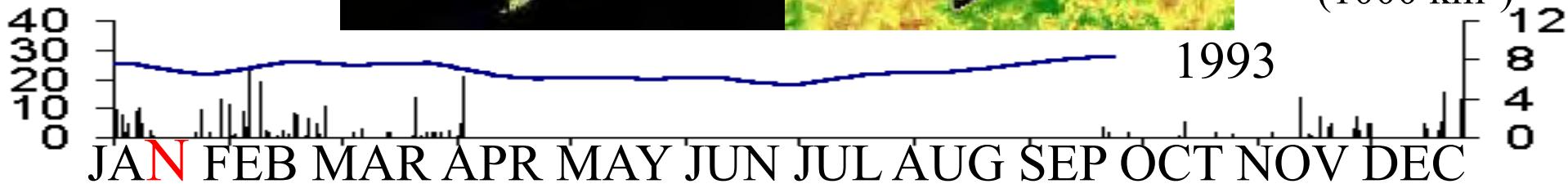
True  
colours



Water



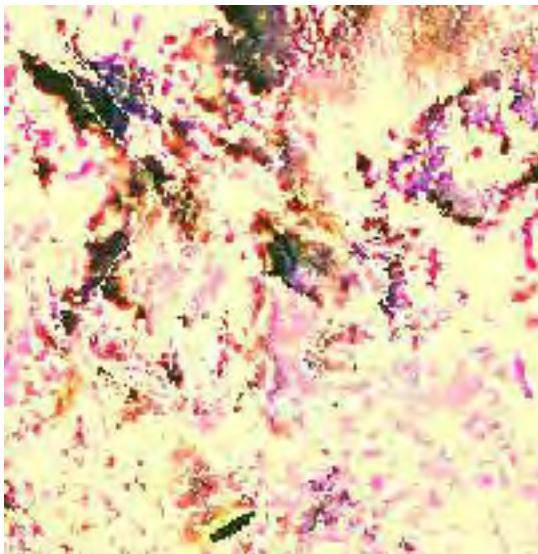
Precipitation  
(mm)



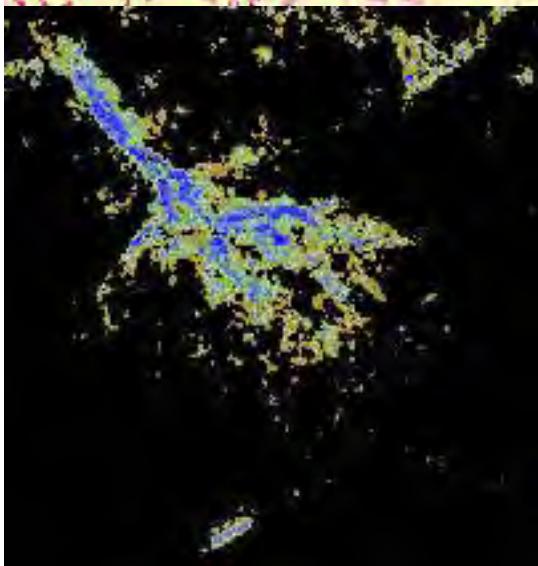
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

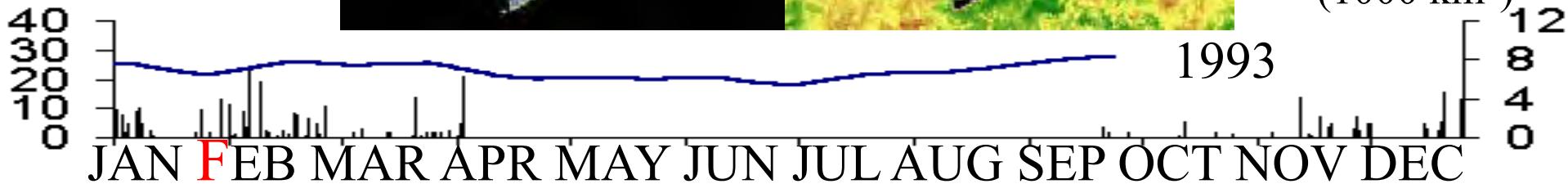
True  
colours



Water



Precipitation  
(mm)



Clouds

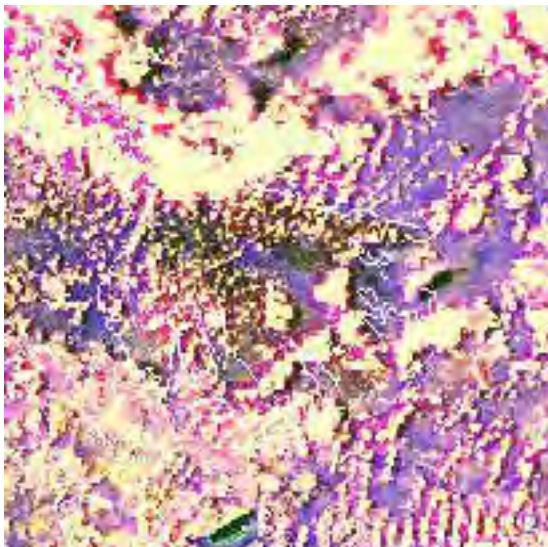
NDVI

N  
100 Km

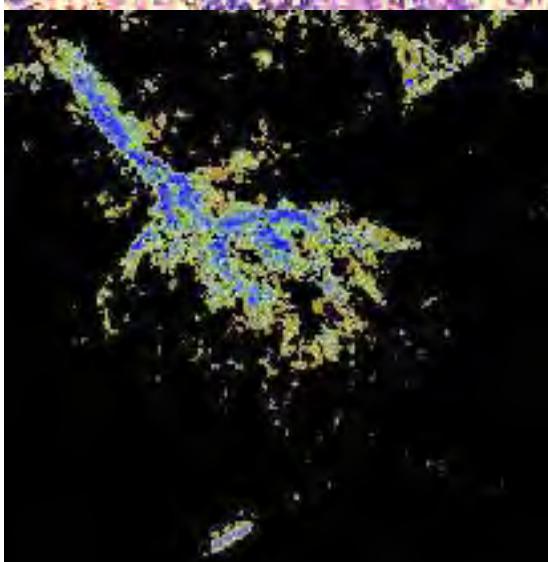
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

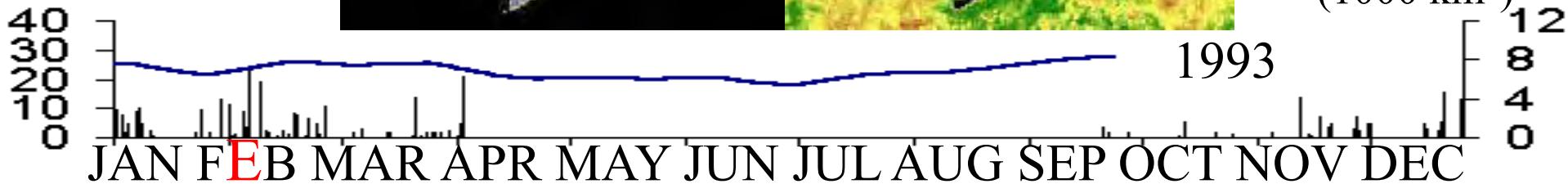
True  
colours



Water



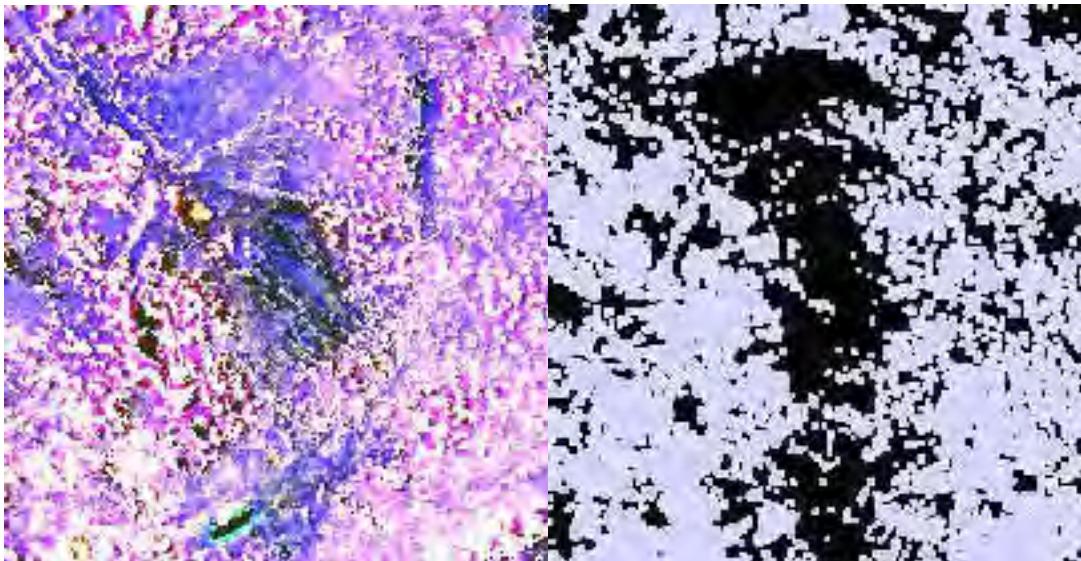
Precipitation  
(mm)



# Okavango Delta, Botswana

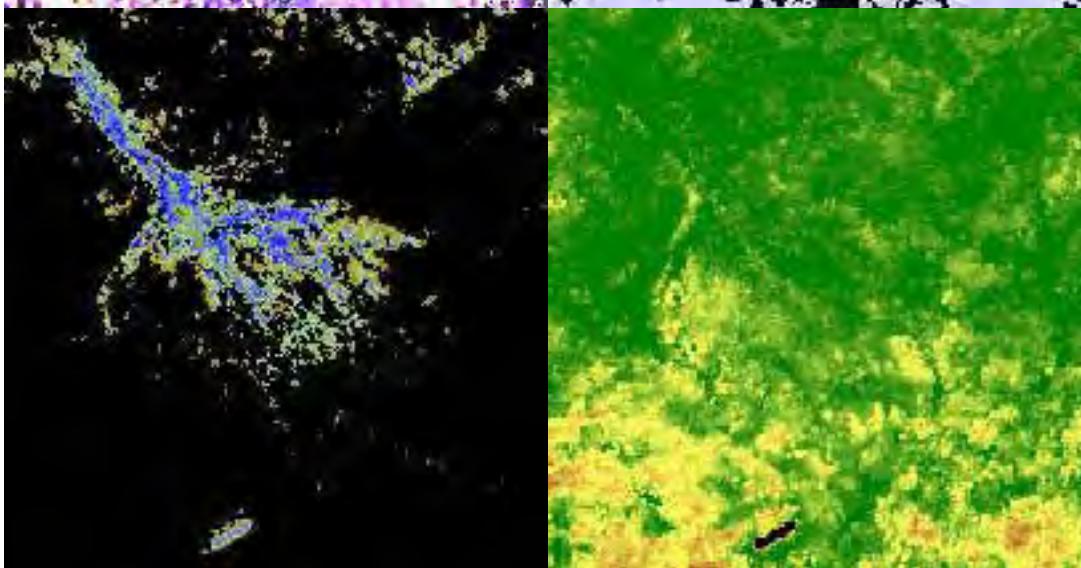
NOAA-  
AVHRR  
Images

True  
colours



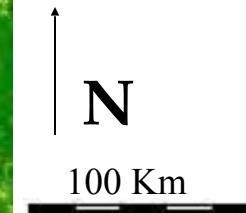
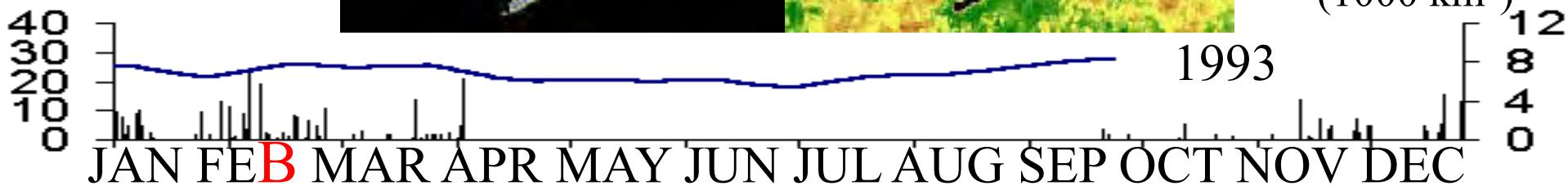
Clouds

Water



NDVI

Precipitation  
(mm)



100 Km

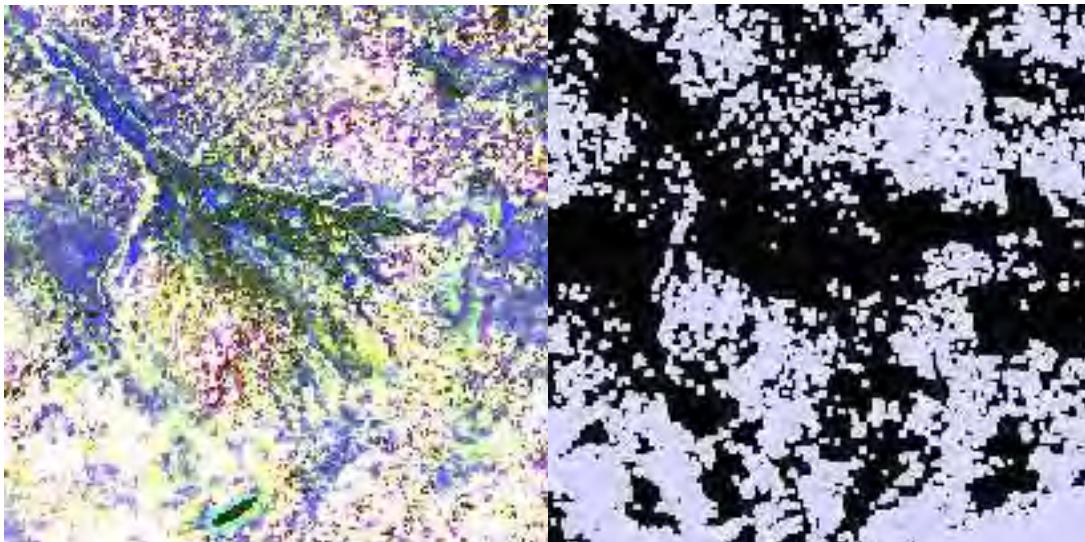
Water area  
(1000 km<sup>2</sup>)

12  
8  
4  
0

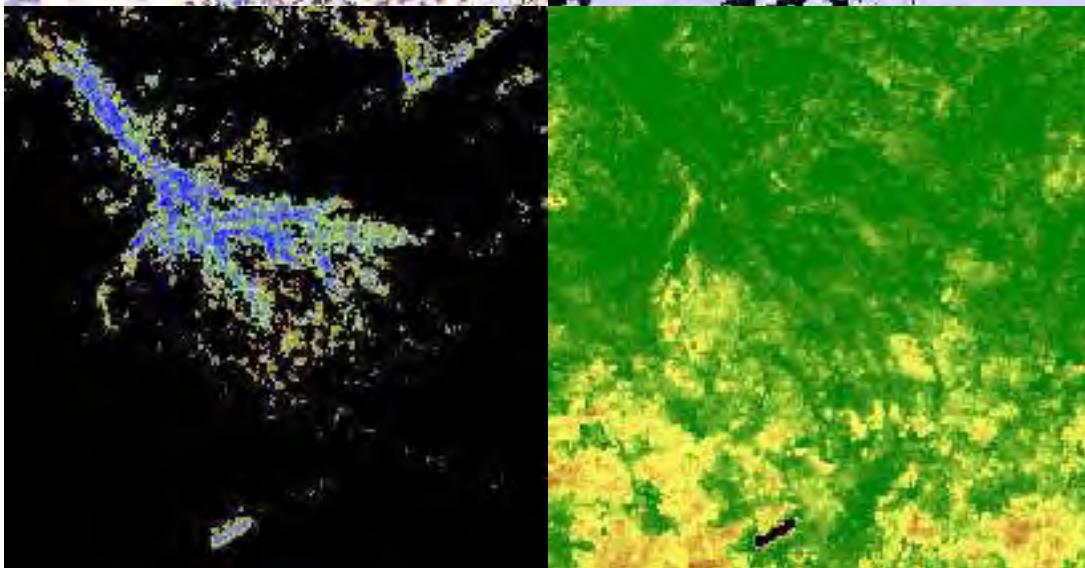
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

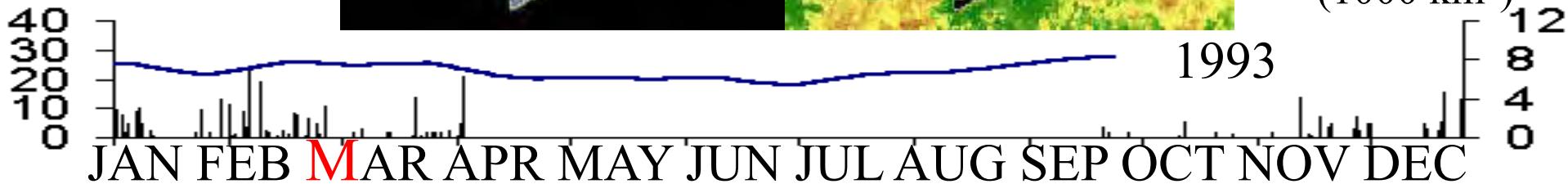
True  
colours



Water



Precipitation  
(mm)



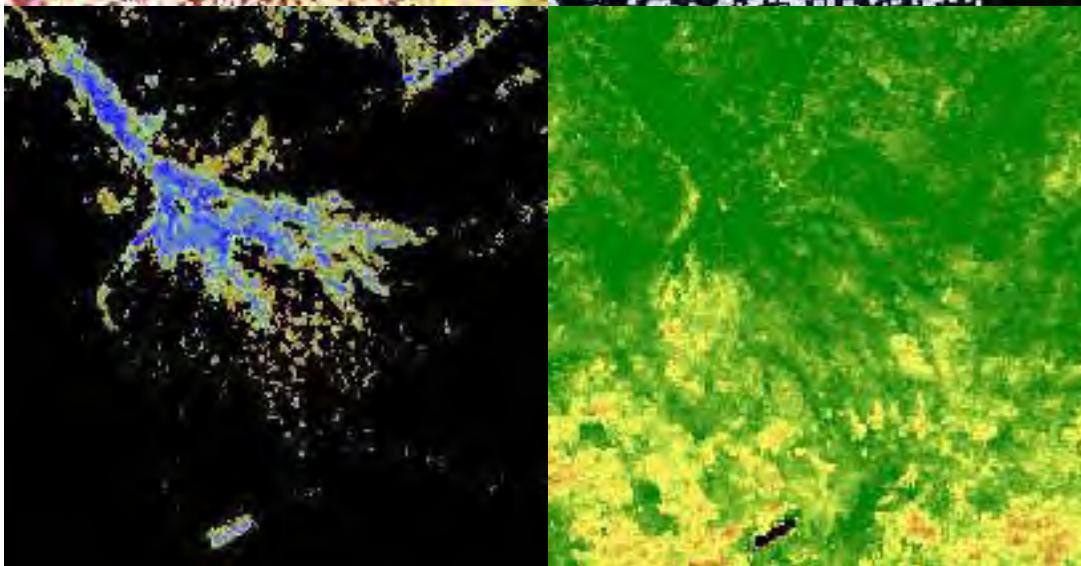
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

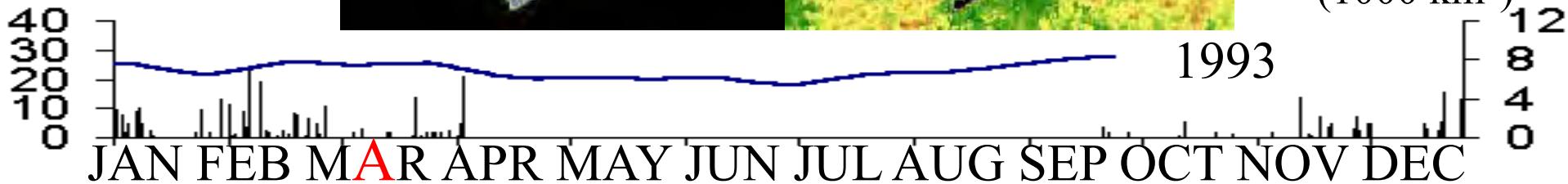
True  
colours



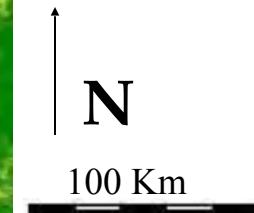
Water



Precipitation  
(mm)



Clouds  
NDVI



Water area  
(1000 km<sup>2</sup>)

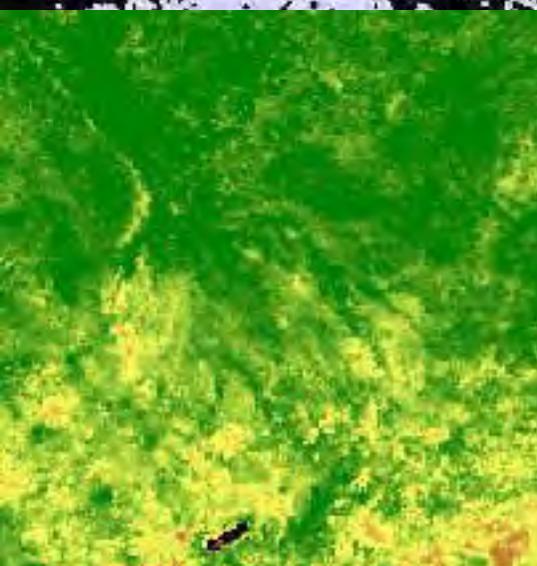
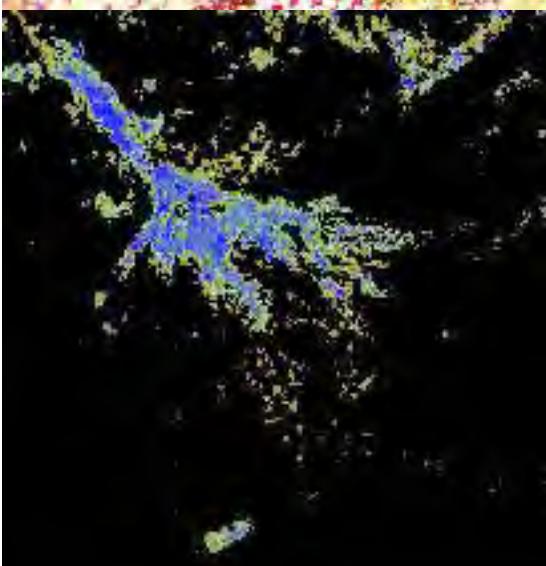
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

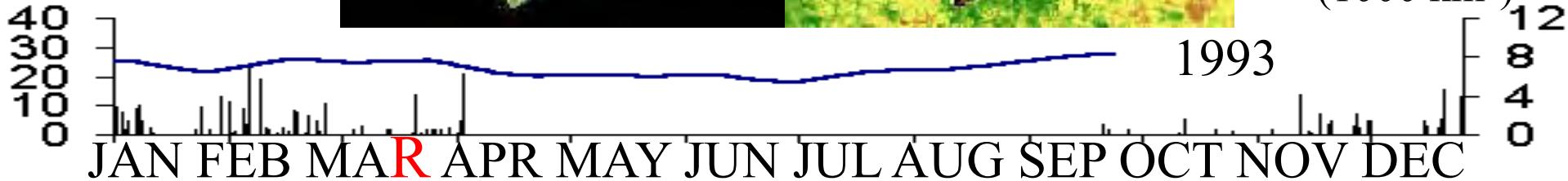
True  
colours



Water



Precipitation  
(mm)



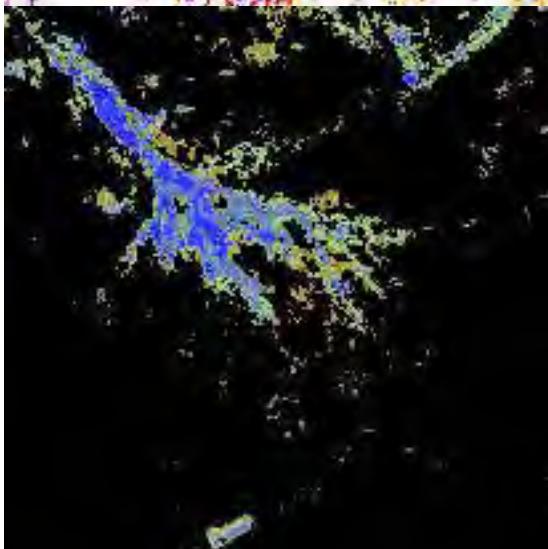
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

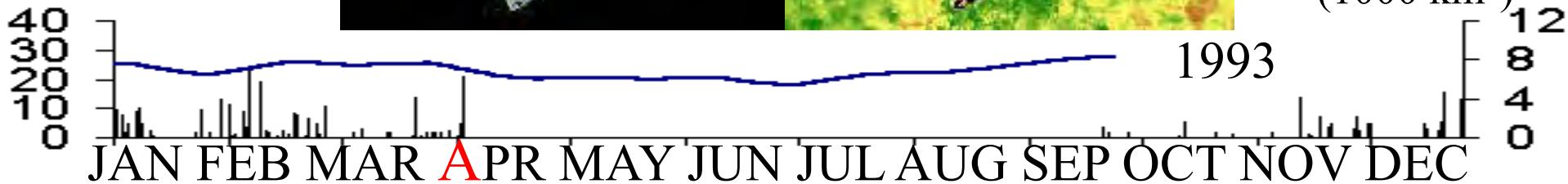
True  
colours



Water



Precipitation  
(mm)



Clouds

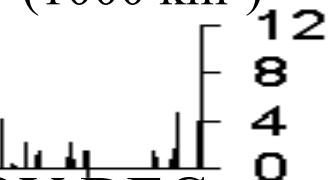


NDVI



N  
100 Km

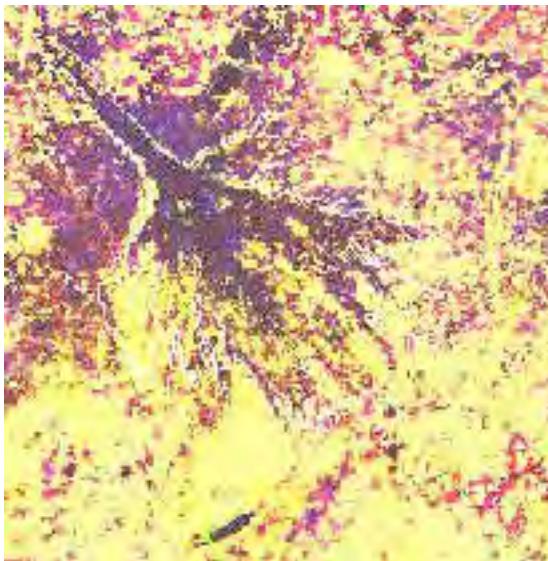
Water area  
(1000 km<sup>2</sup>)



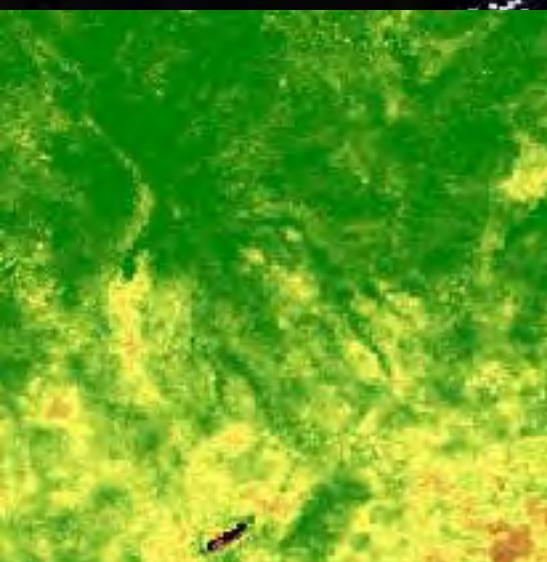
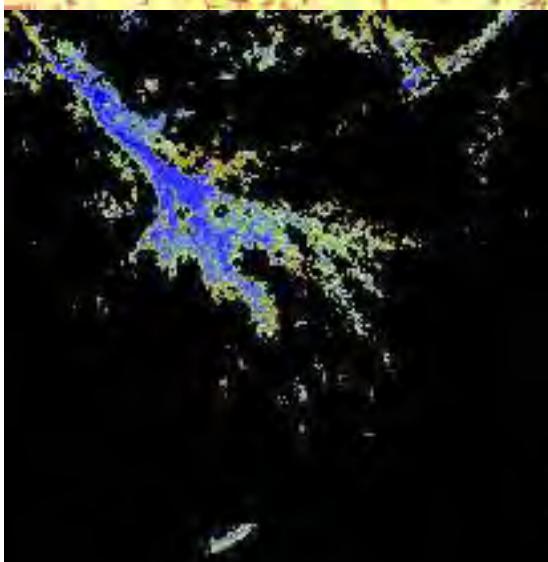
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

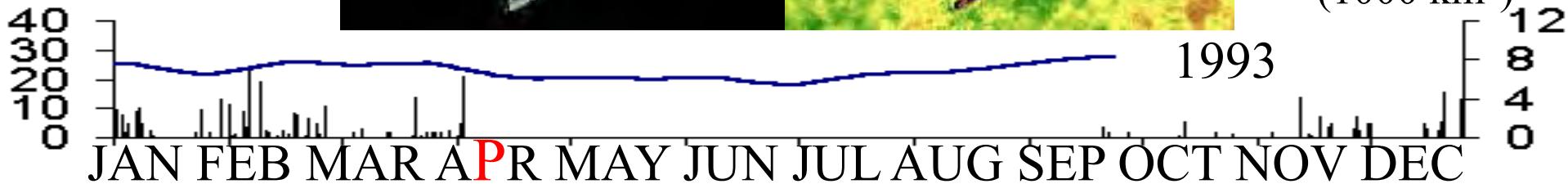
True  
colours



Water

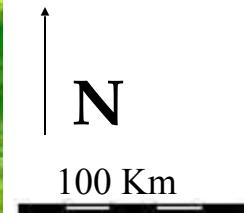


Precipitation  
(mm)



Clouds

NDVI

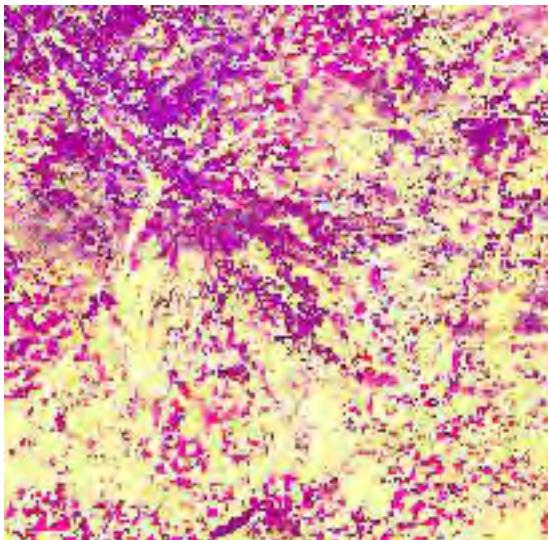


Water area  
(1000 km<sup>2</sup>)

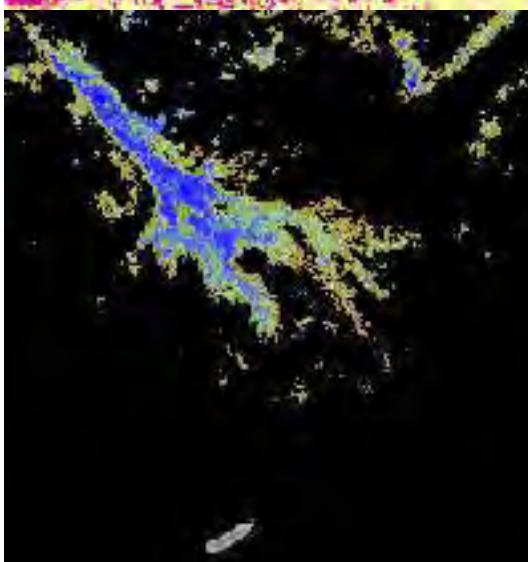
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



Water

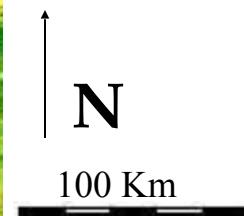
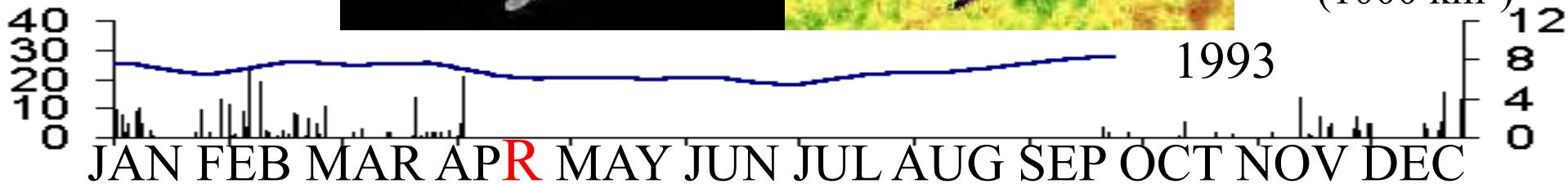


Clouds



NDVI

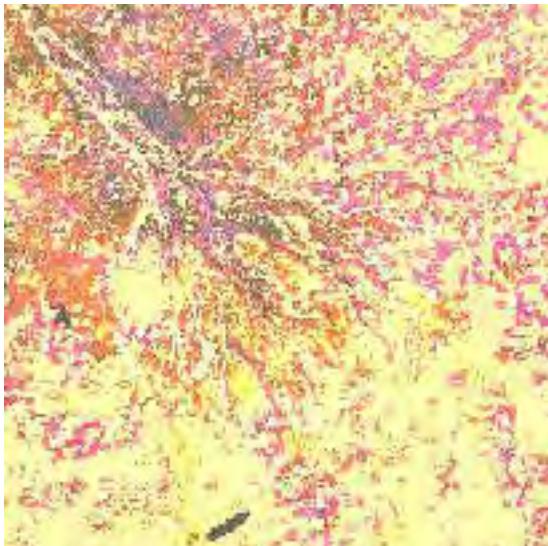
Precipitation  
(mm)



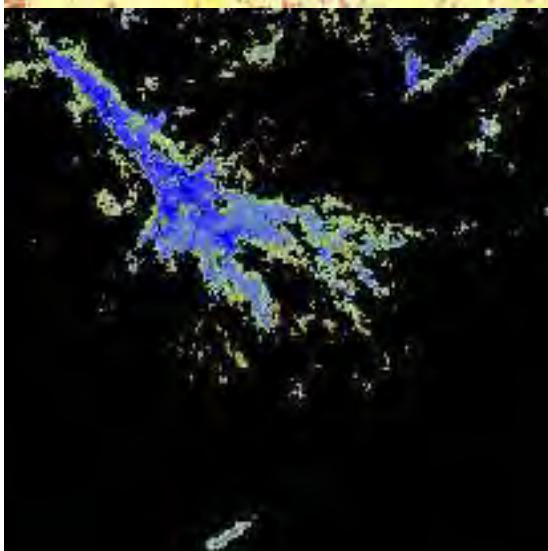
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

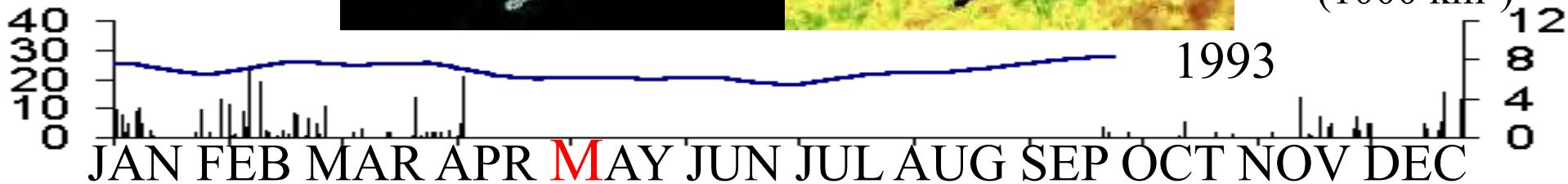
True  
colours



Water



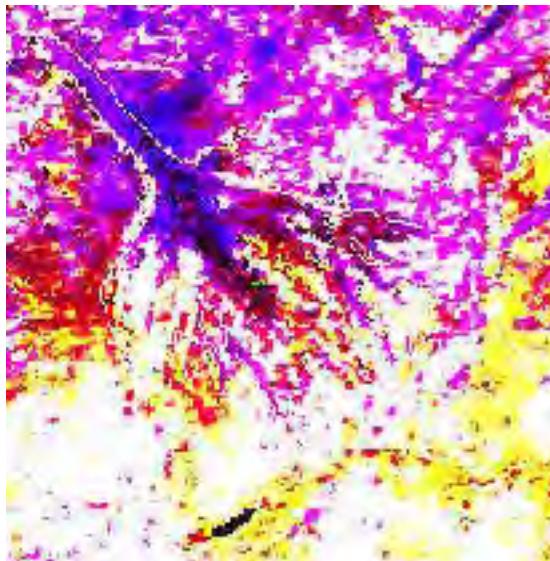
Precipitation  
(mm)



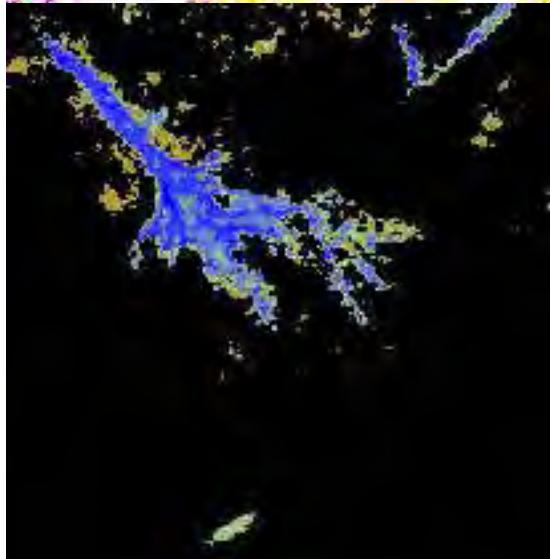
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

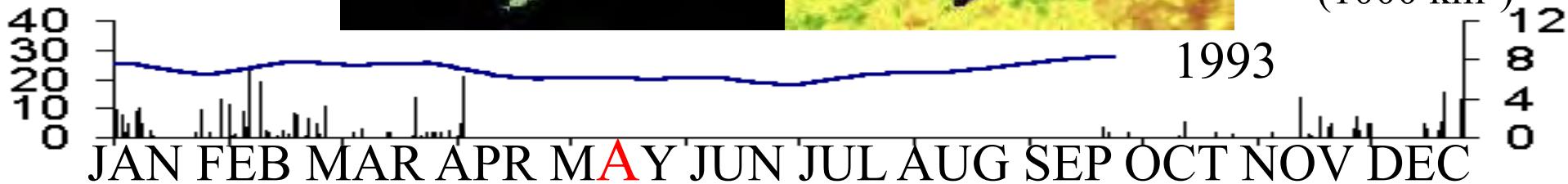
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

↑ N

100 Km

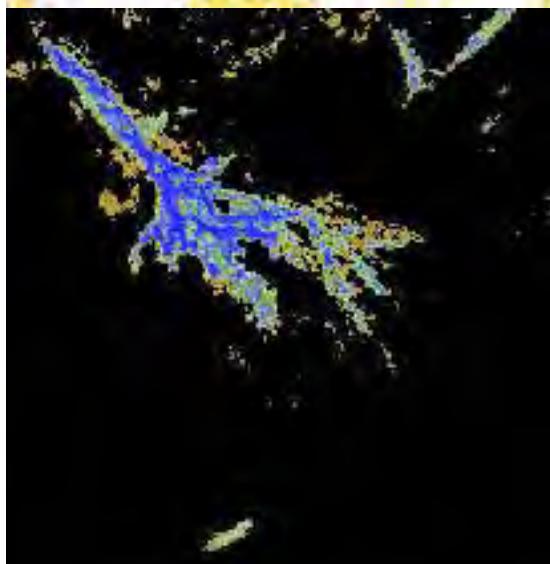
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

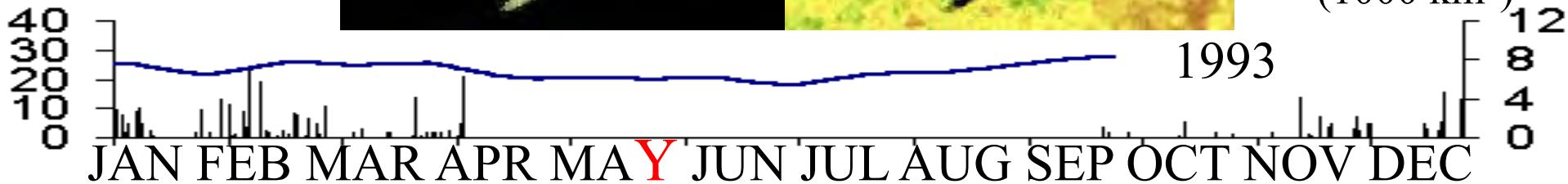
True  
colours



Water

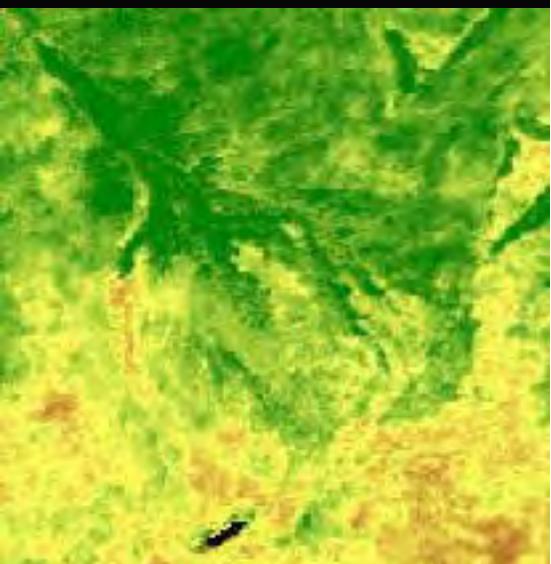
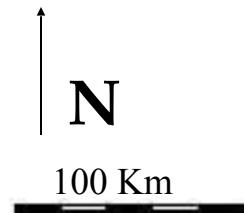


Precipitation  
(mm)



Clouds

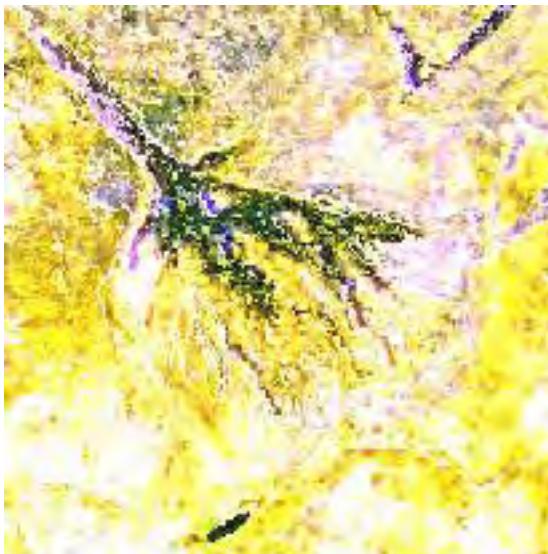
NDVI



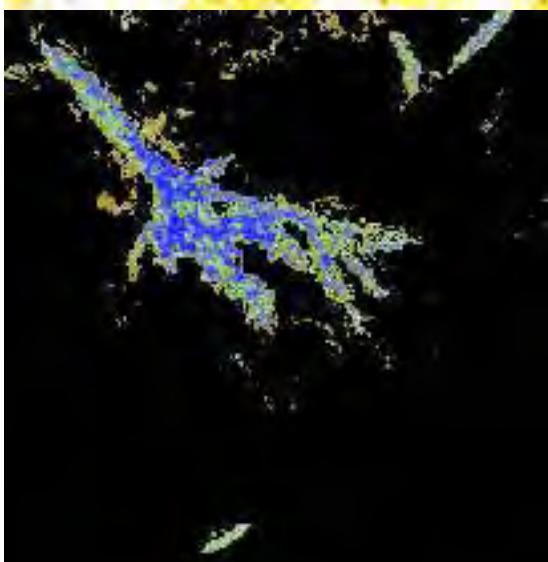
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

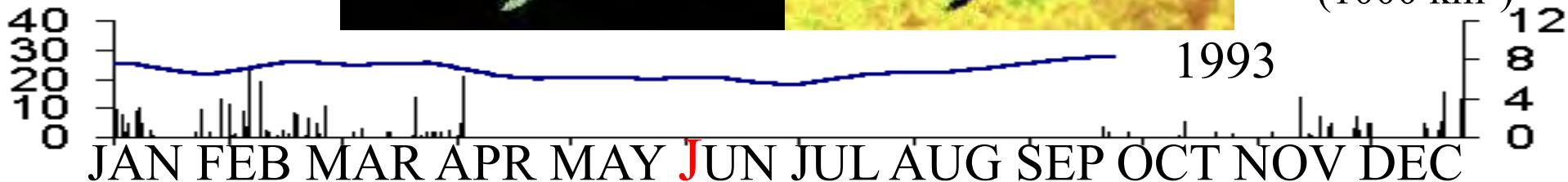
True  
colours



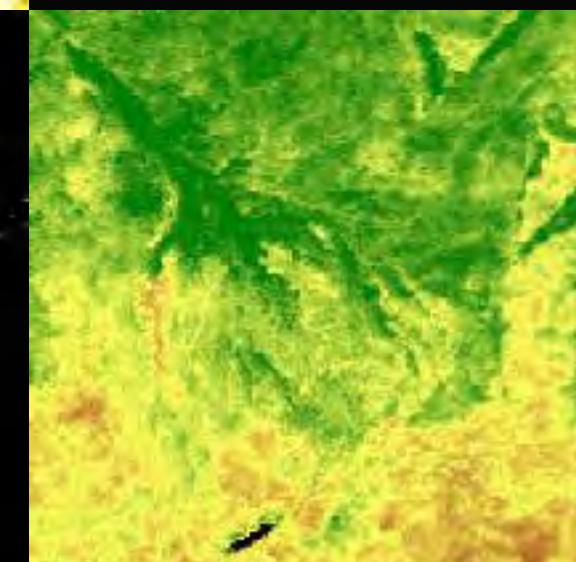
Water



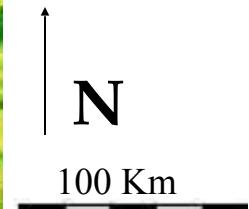
Precipitation  
(mm)



Clouds

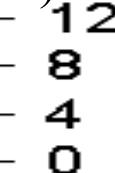


NDVI



Water area  
(1000 km<sup>2</sup>)

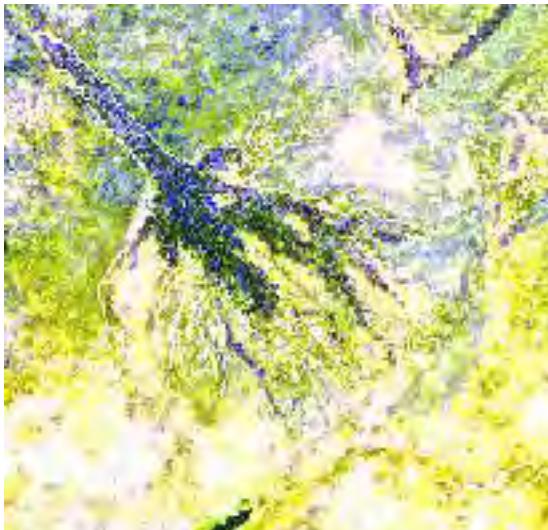
1993



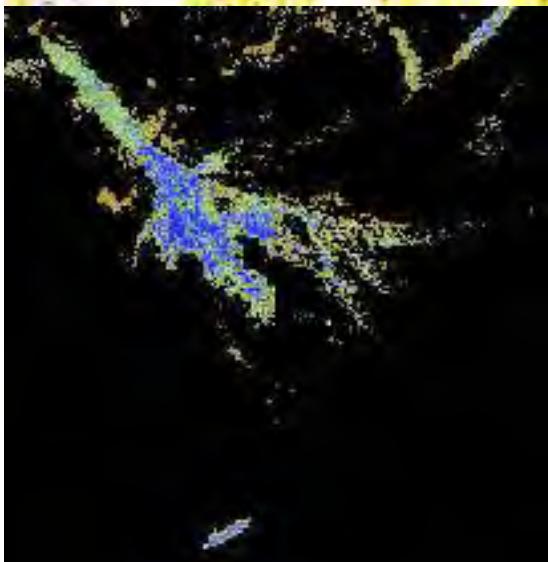
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

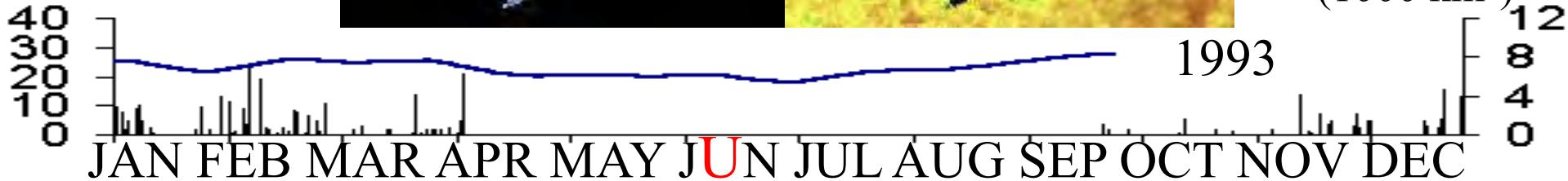
True  
colours



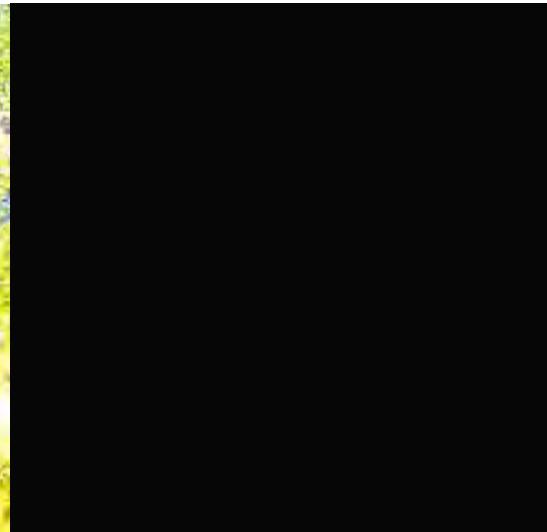
Water



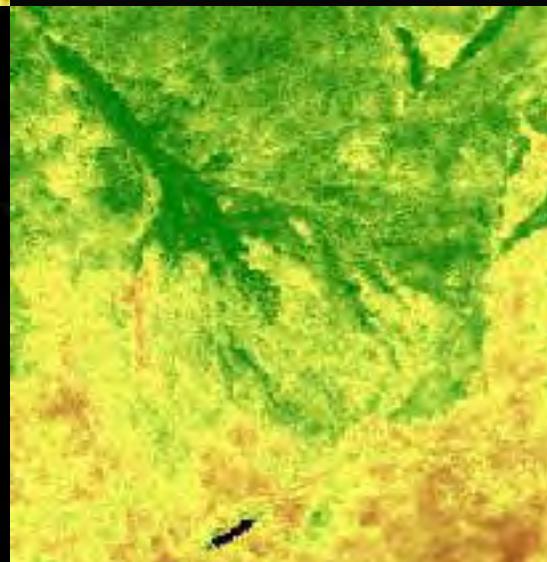
Precipitation  
(mm)



Clouds



NDVI



N

100 Km

Water area  
(1000 km²)

1993

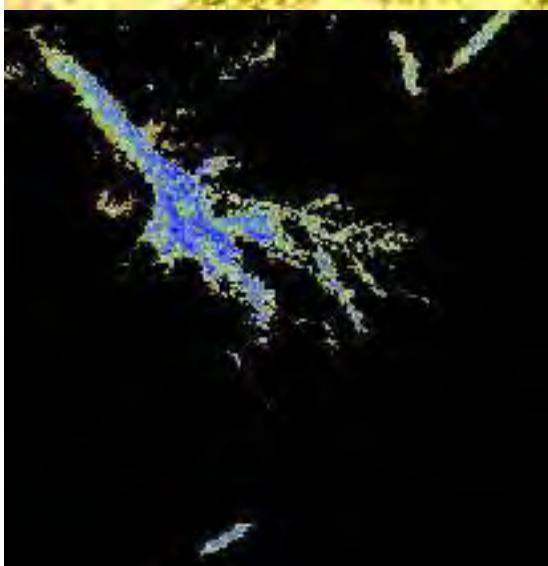
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

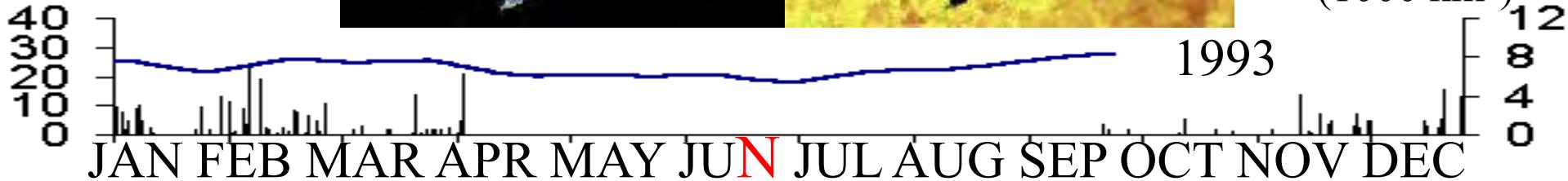
True  
colours



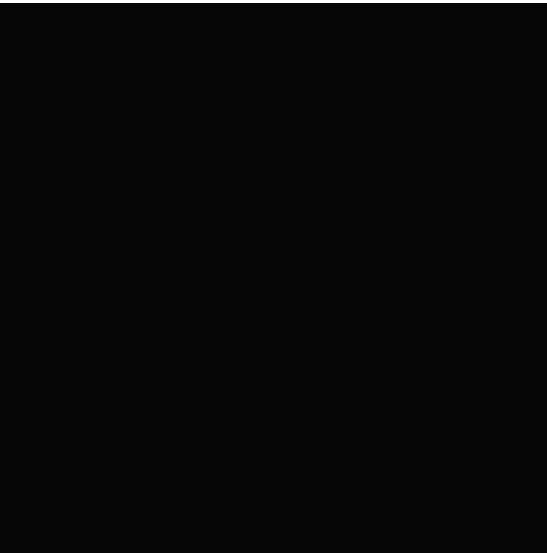
Water



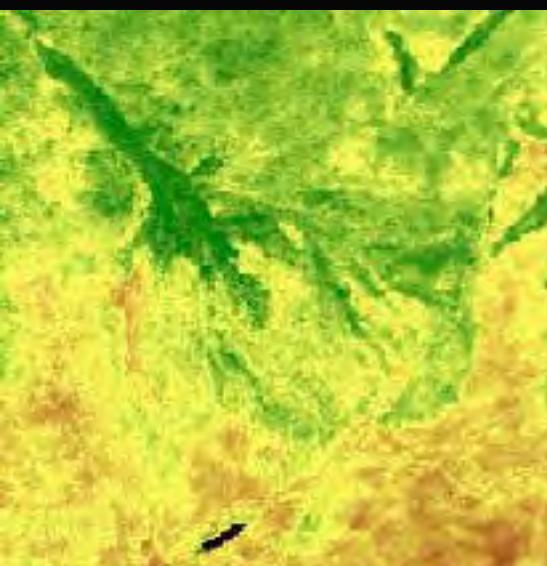
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
(1000 km<sup>2</sup>)

1993

12  
8  
4  
0

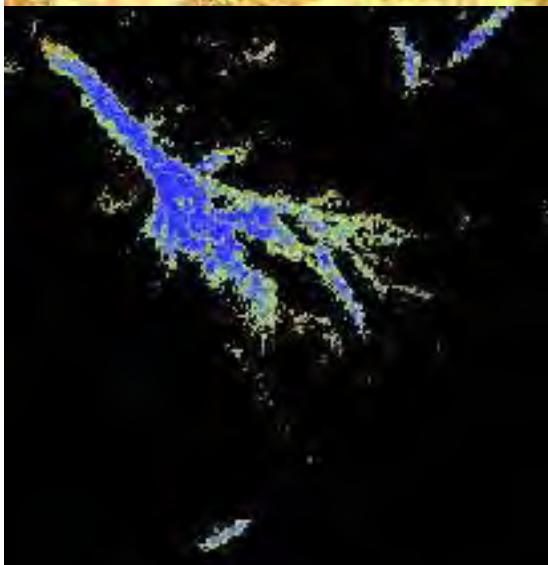
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

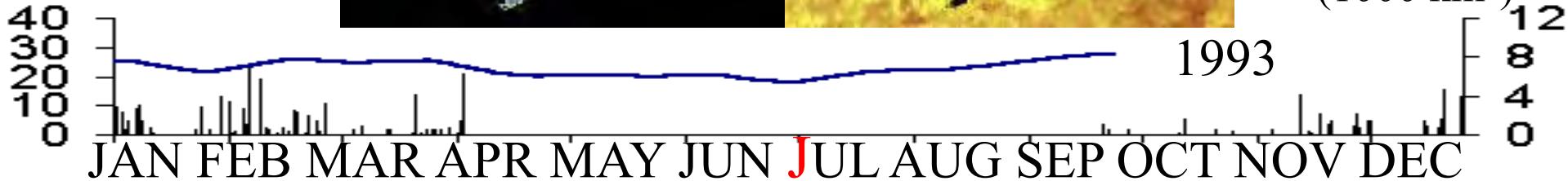
True  
colours



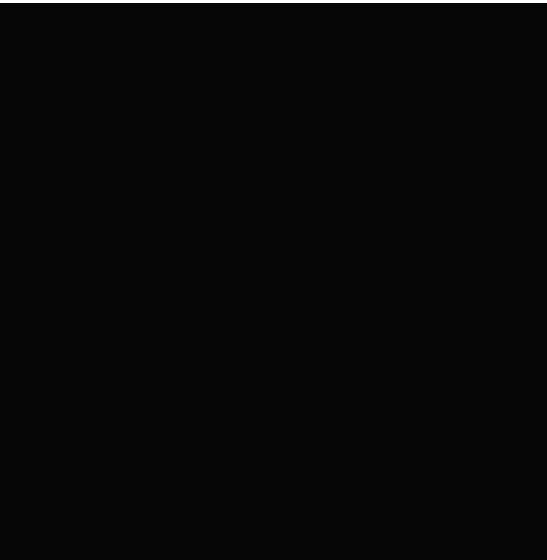
Water



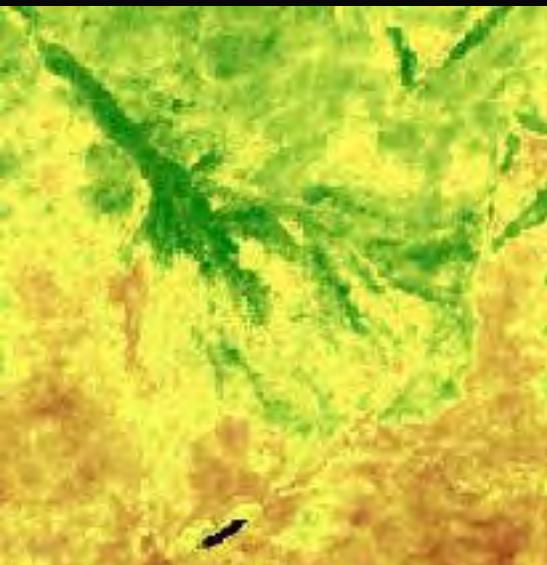
Precipitation  
(mm)



Clouds



NDVI



N

100 Km

Water area  
(1000 km<sup>2</sup>)

1993

12  
8  
4  
0

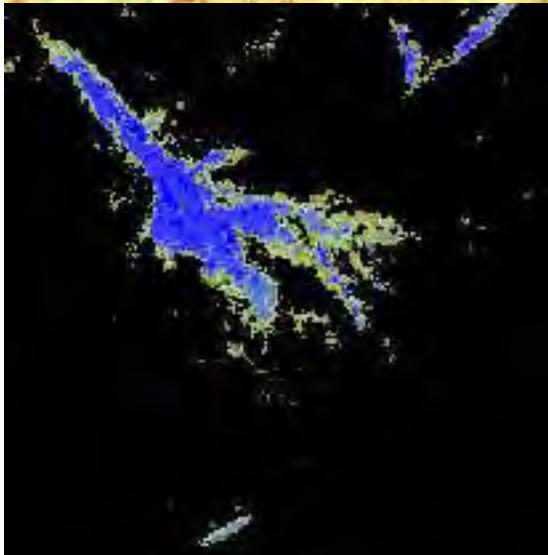
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

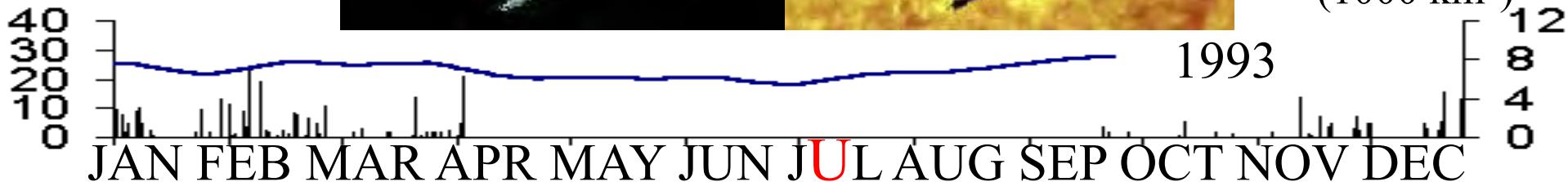
True  
colours



Water



Precipitation  
(mm)



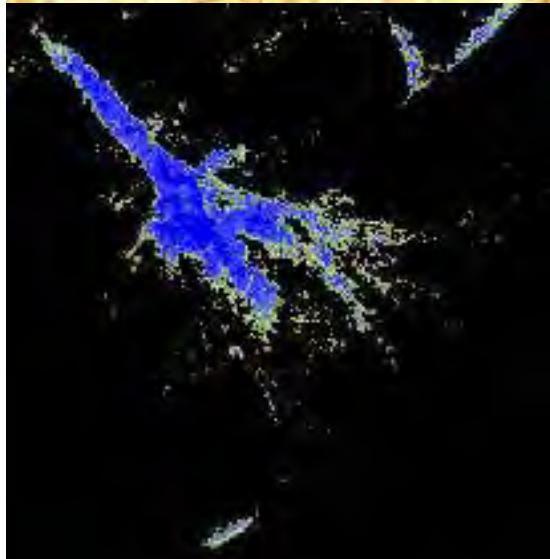
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

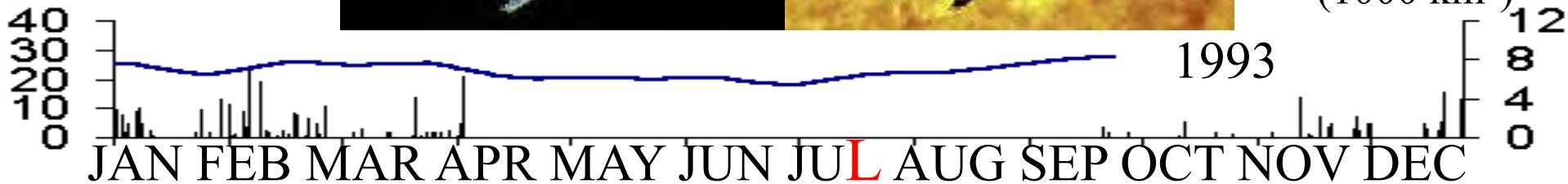
True  
colours



Water



Precipitation  
(mm)



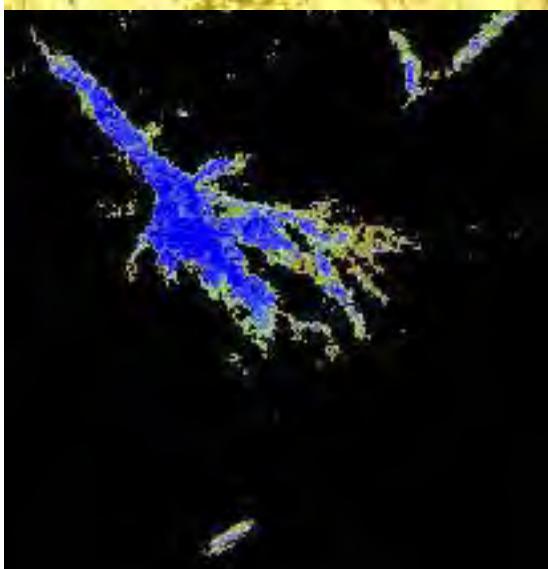
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

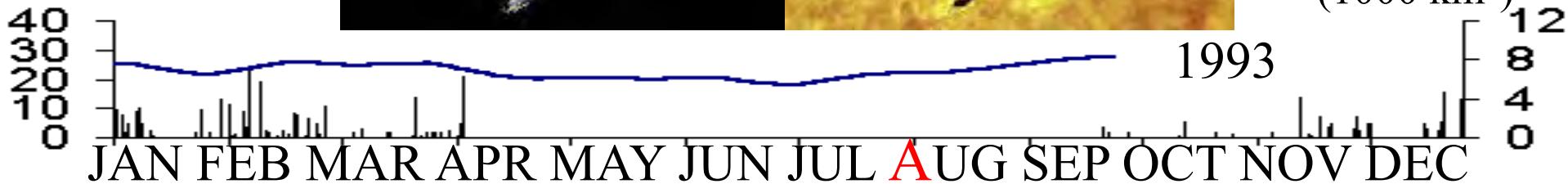
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

N  
↑

100 Km

Water area  
(1000 km<sup>2</sup>)

1993

12  
8  
4  
0

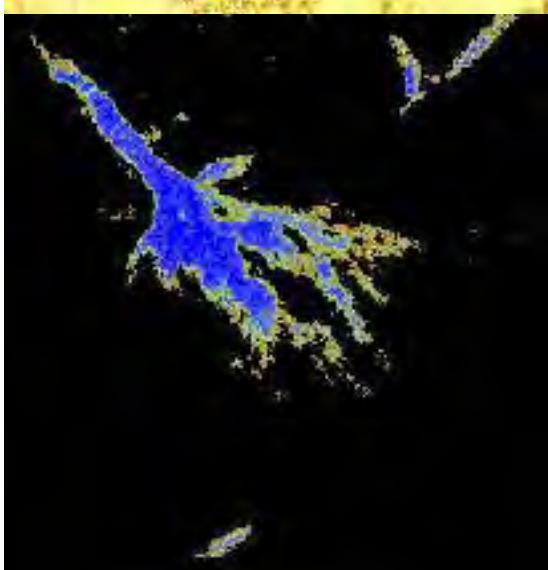
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

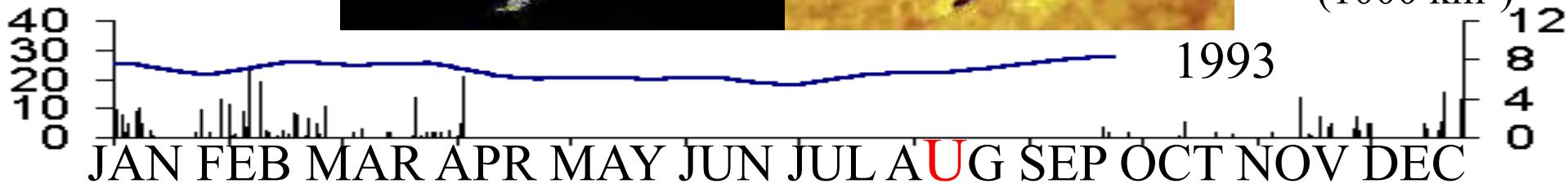
True  
colours



Water



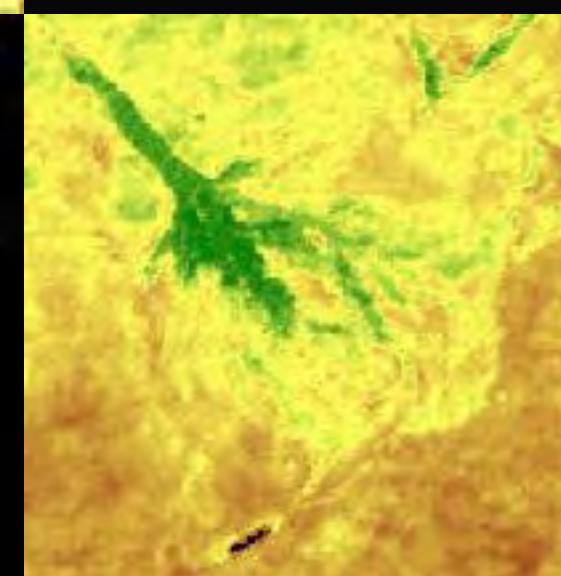
Precipitation  
(mm)



Clouds



NDVI



↑ N  
100 Km

Water area  
(1000 km<sup>2</sup>)

1993

12  
8  
4  
0

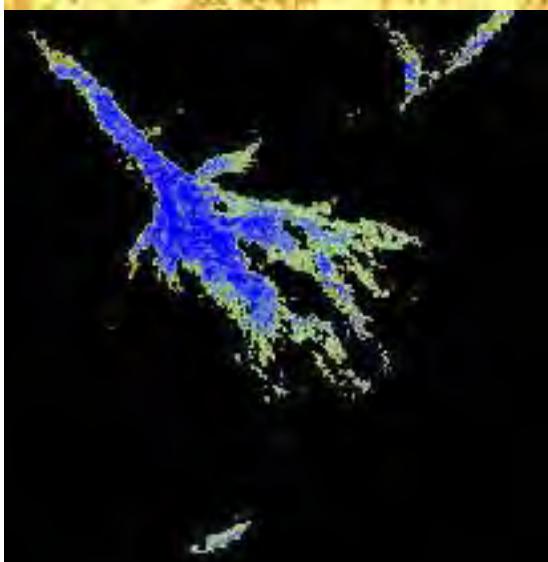
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

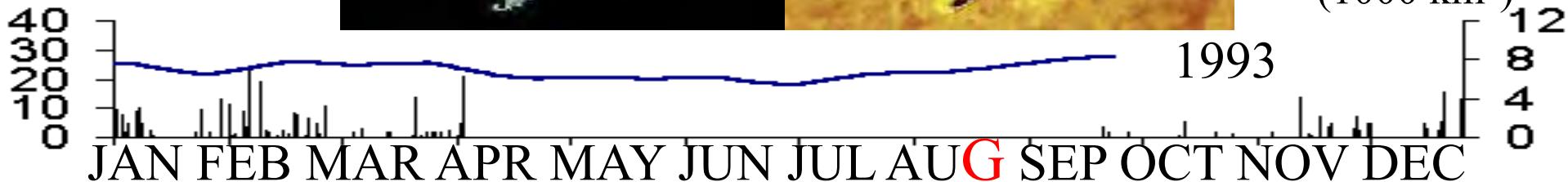
True  
colours



Water



Precipitation  
(mm)



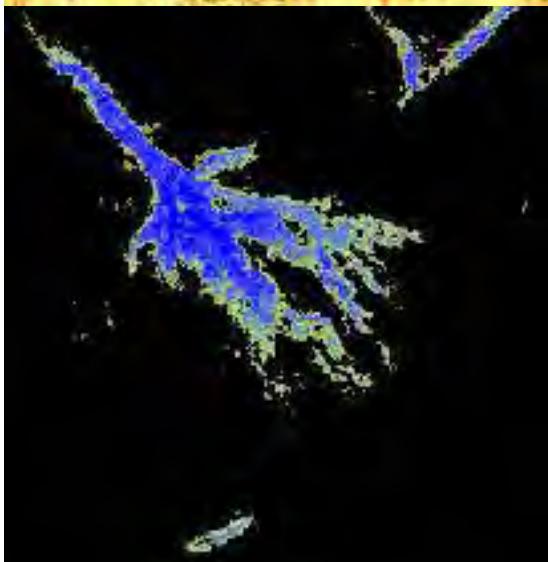
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

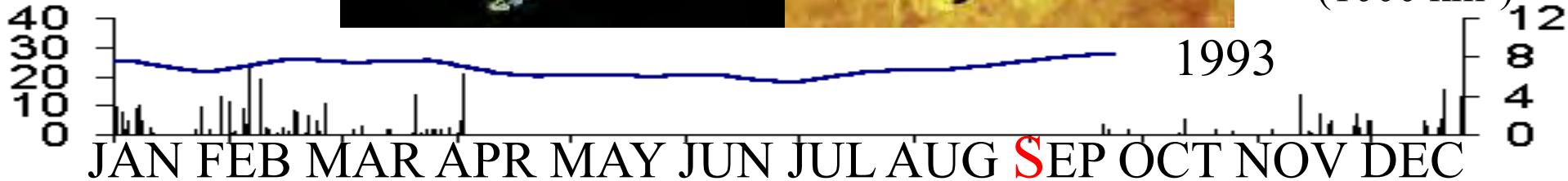
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

N  
100 Km

Water area  
(1000 km²)

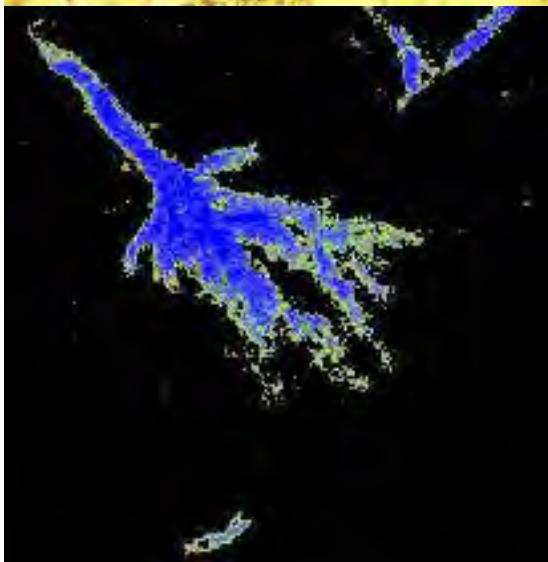
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

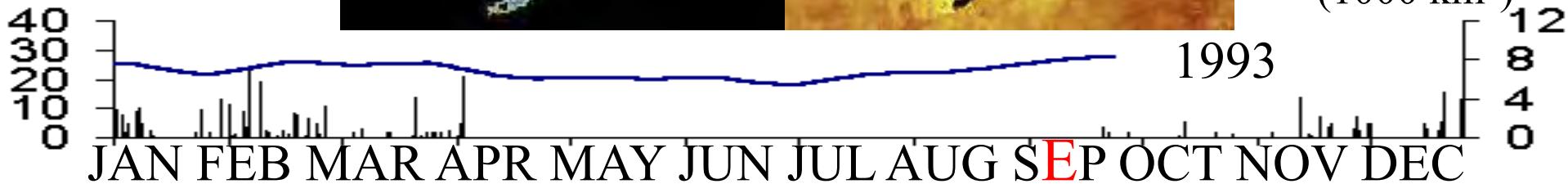
True  
colours



Water



Precipitation  
(mm)



Clouds

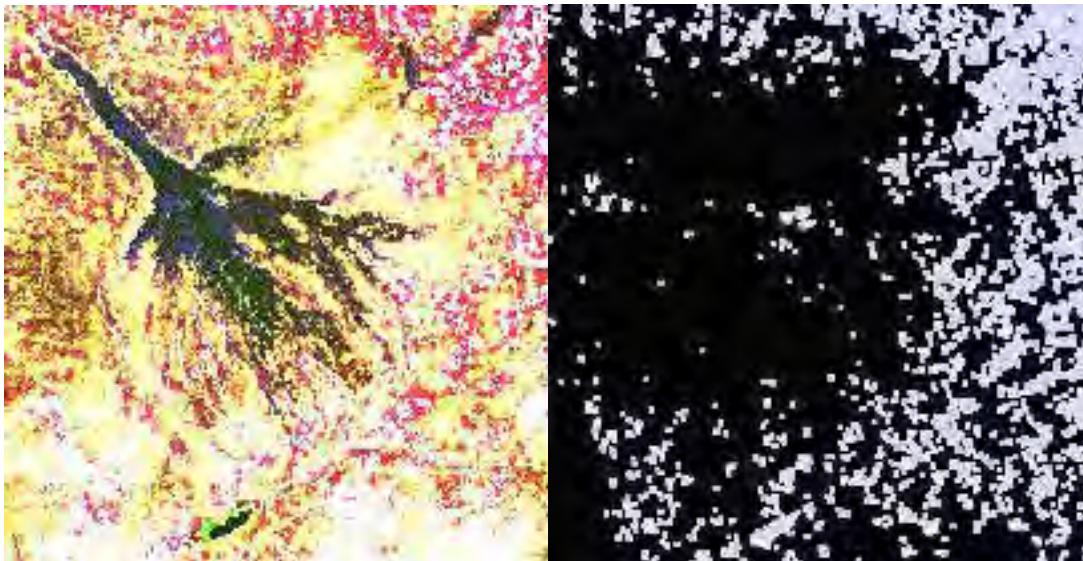
NDVI

N  
100 Km

# Okavango Delta, Botswana

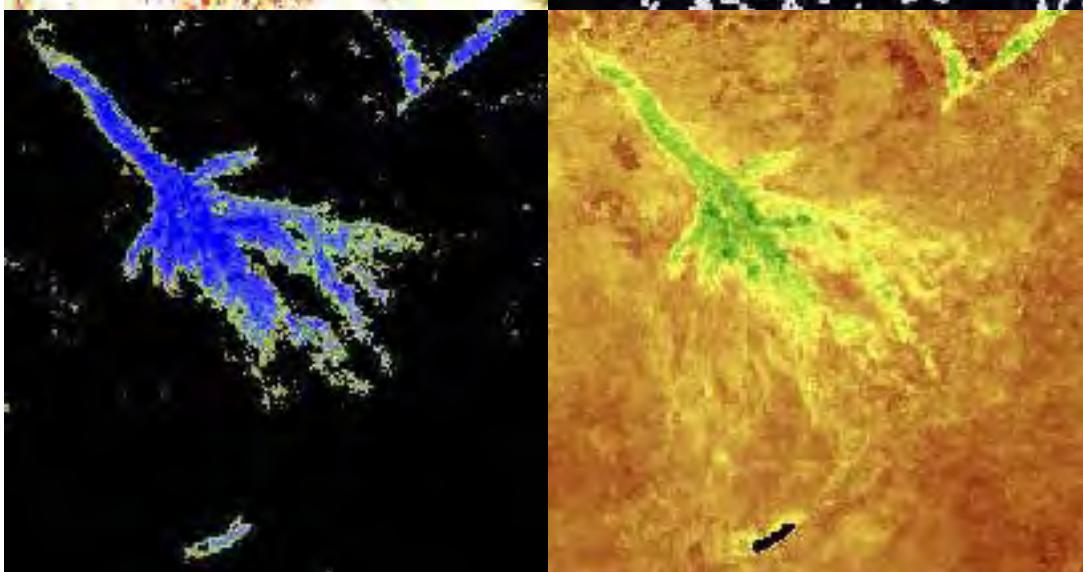
NOAA-  
AVHRR  
Images

True  
colours

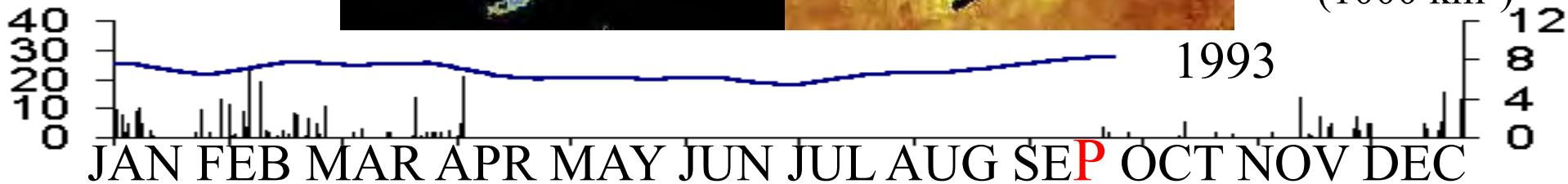


Water

Clouds  
NDVI



Precipitation  
(mm)



# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours  
  
Water

Clouds  
  
NDVI

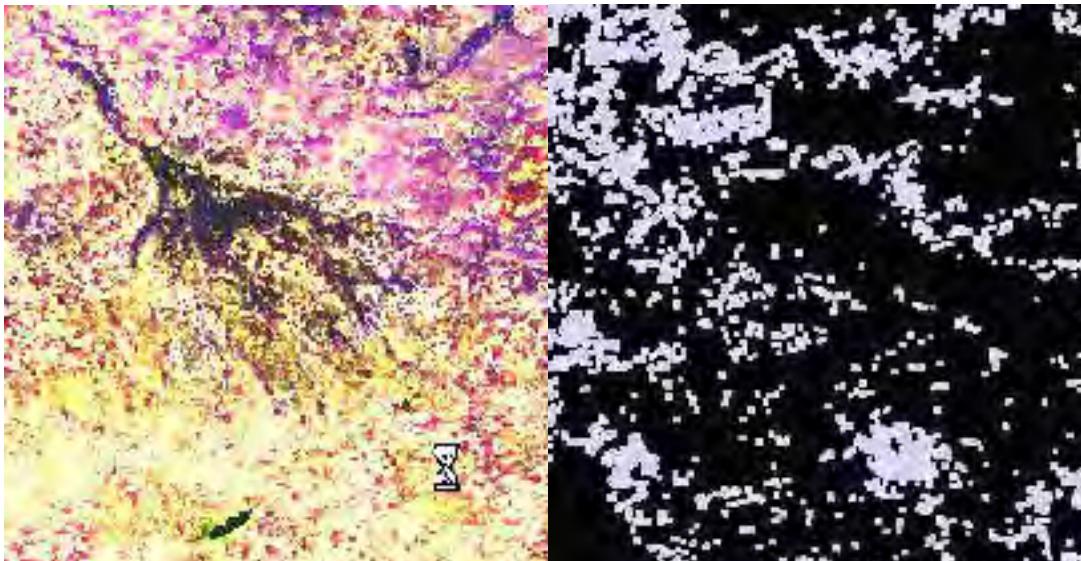
1994 – NO DATA

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

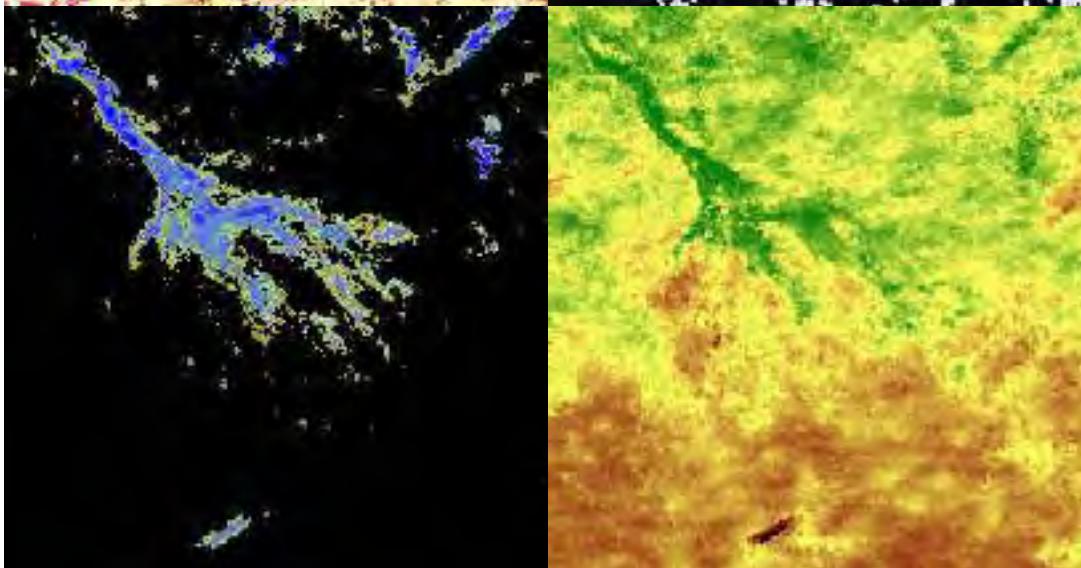
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

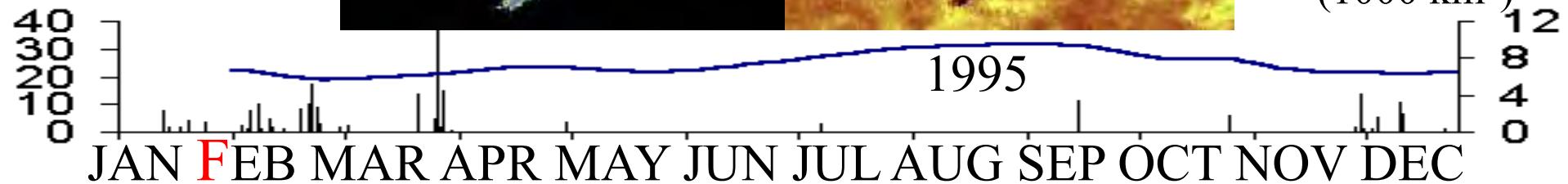
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

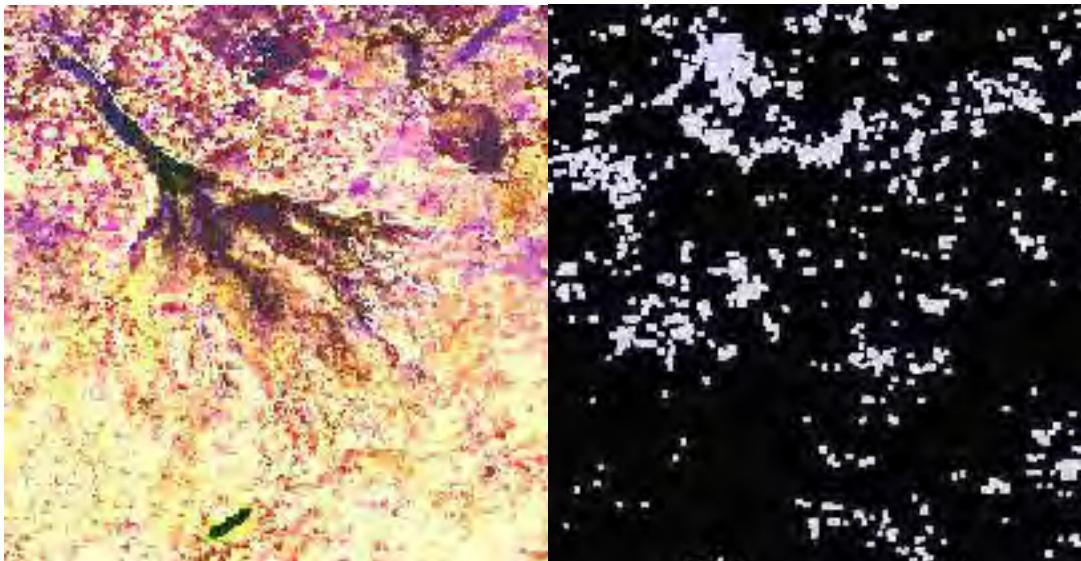
N  
100 Km

Water area  
(1000 km<sup>2</sup>)

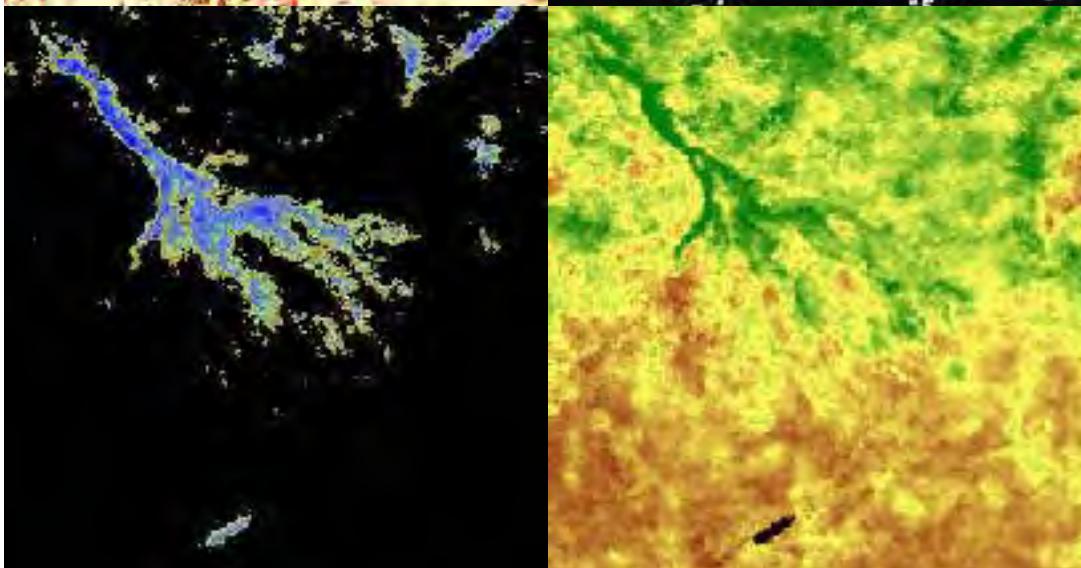
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

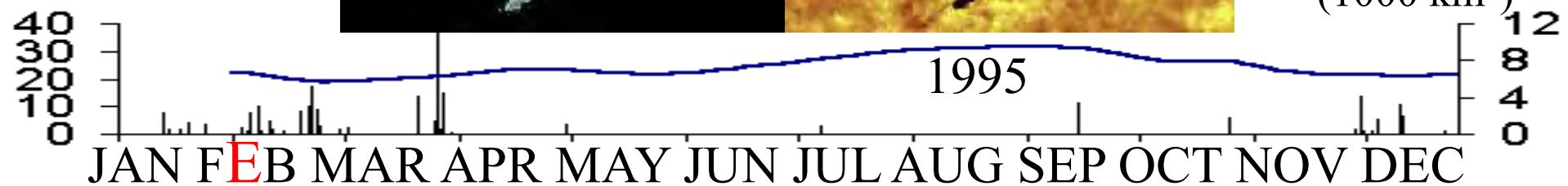
True  
colours



Water



Precipitation  
(mm)



Clouds  
NDVI

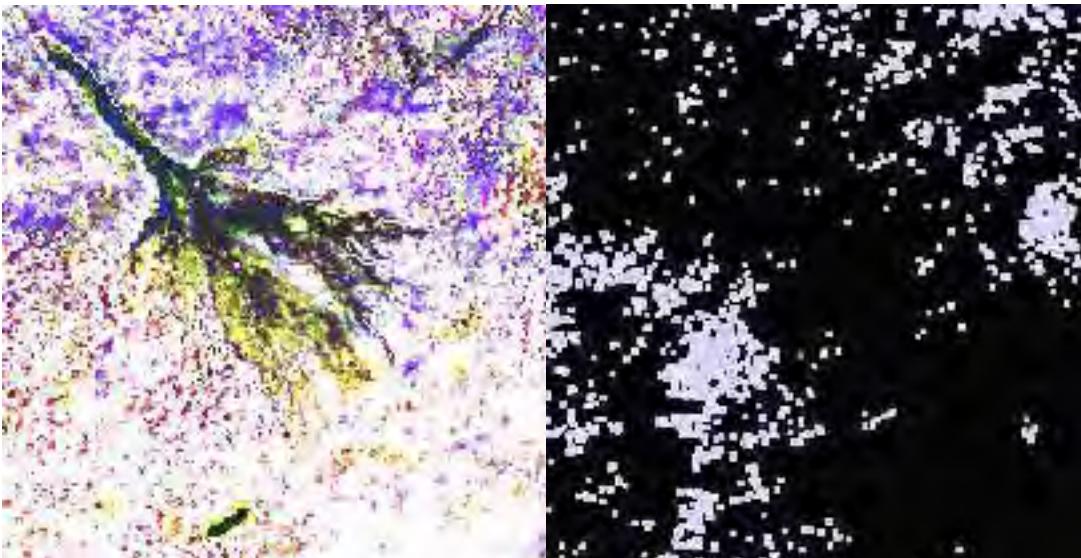
N  
100 Km

Water area  
(1000 km<sup>2</sup>)

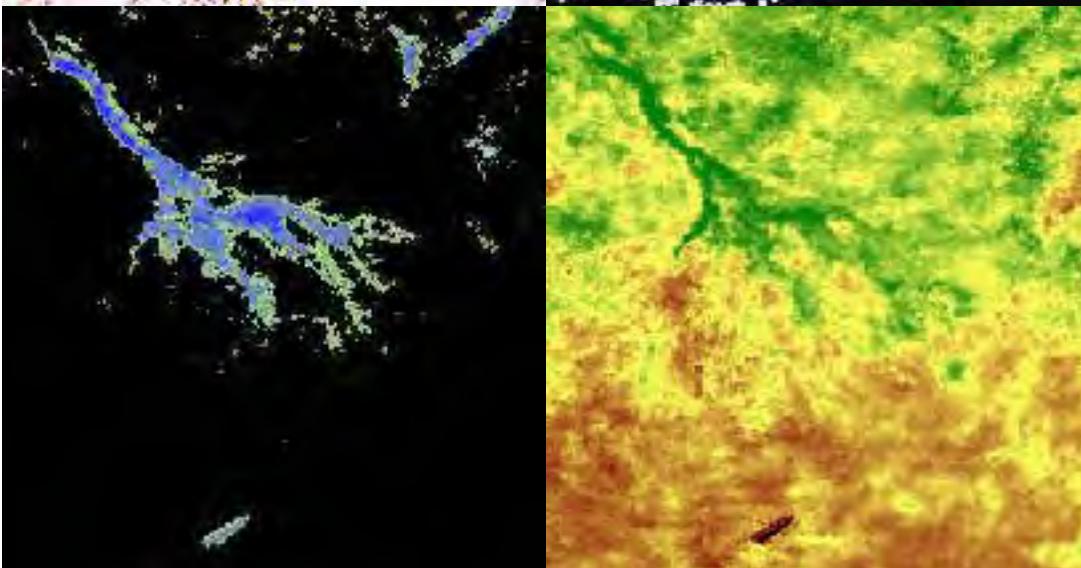
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

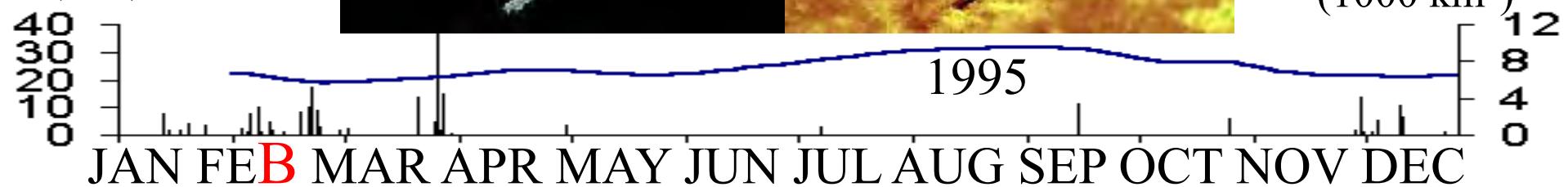
True  
colours



Water



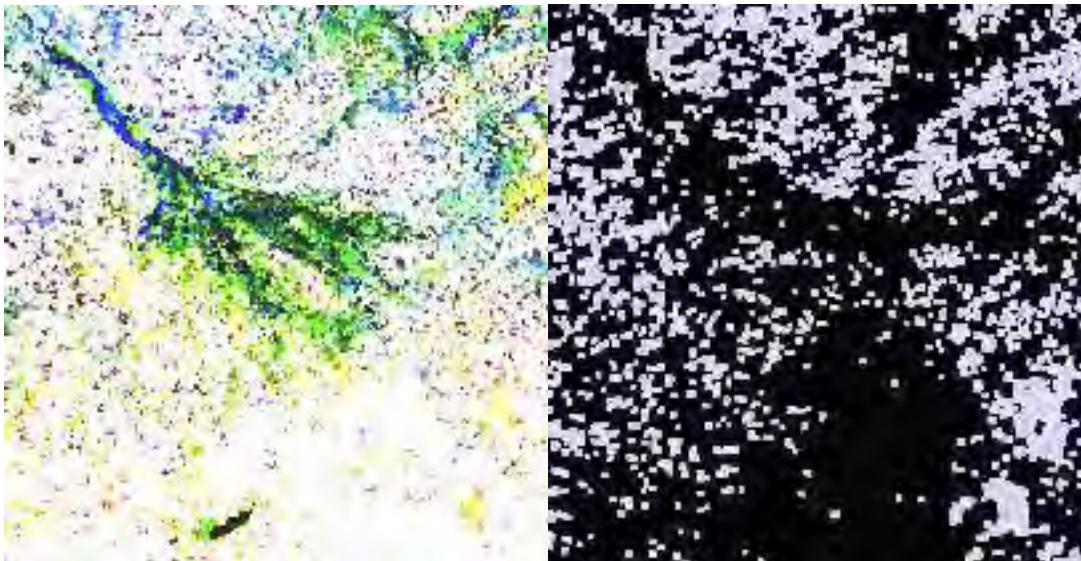
Precipitation  
(mm)



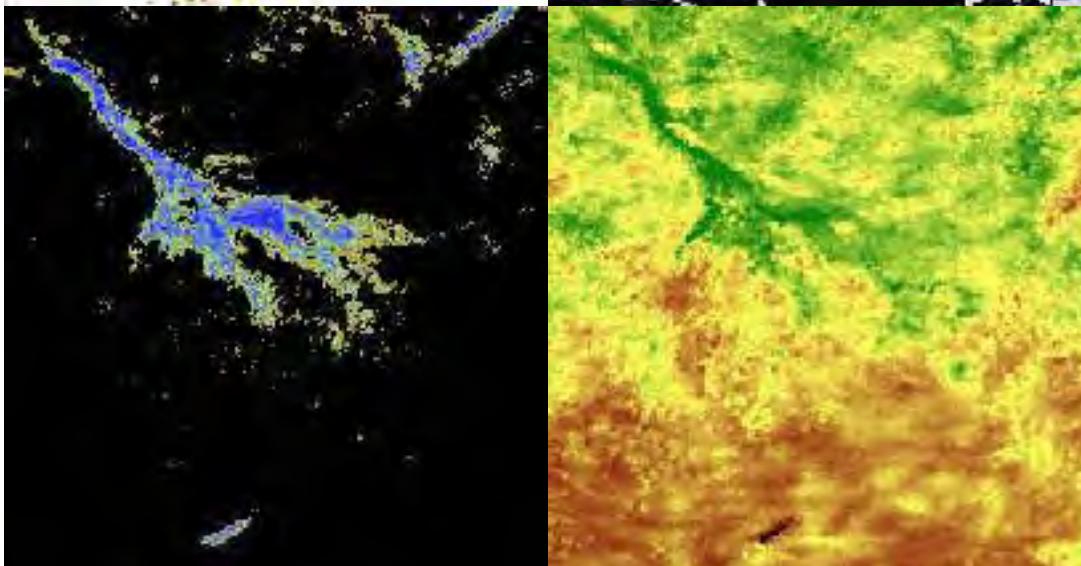
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

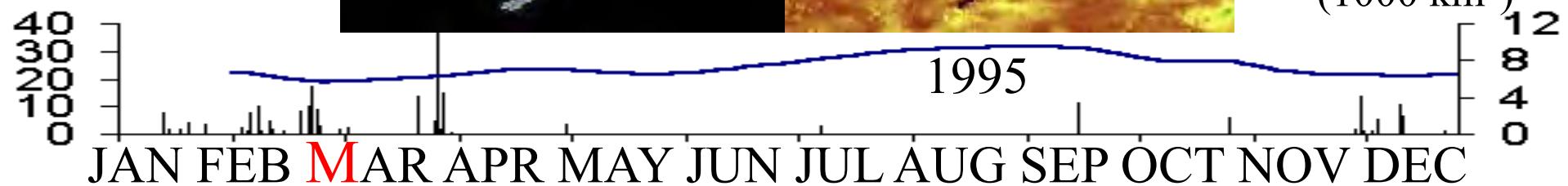
True  
colours



Water



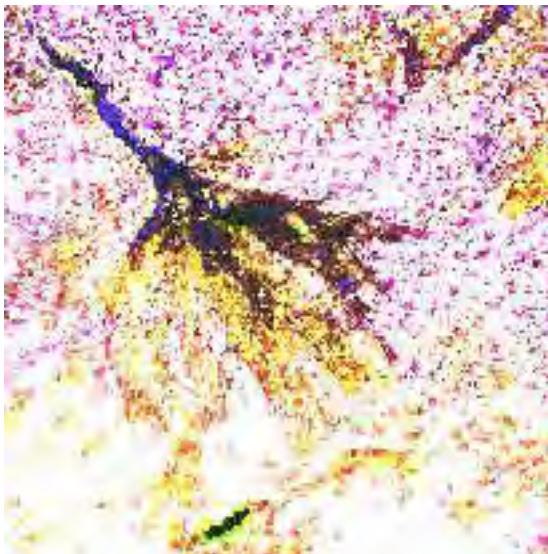
Precipitation  
(mm)



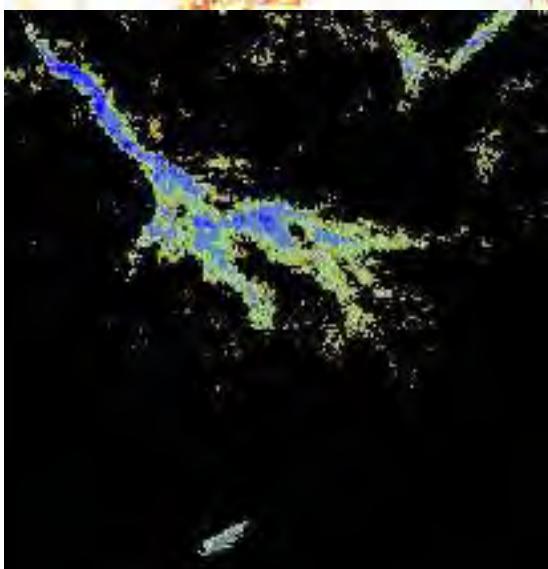
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

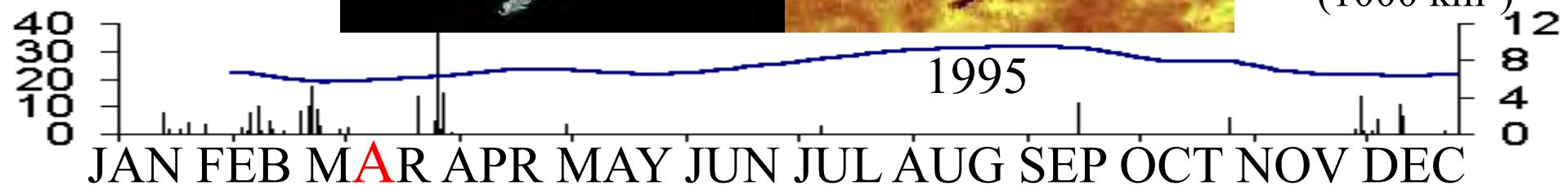
True  
colours



Water



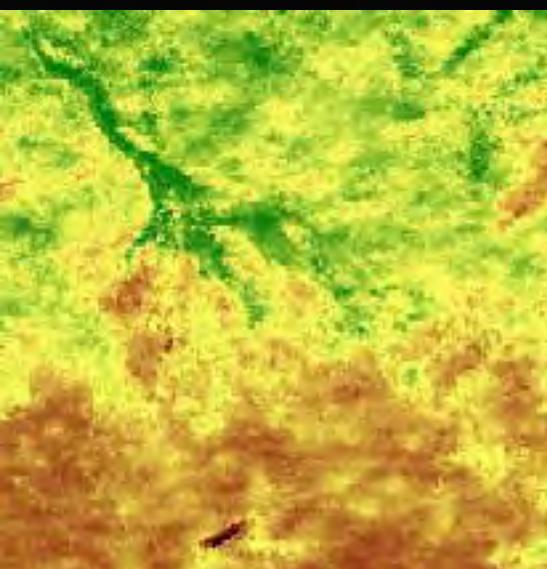
Precipitation  
(mm)



Clouds



NDVI

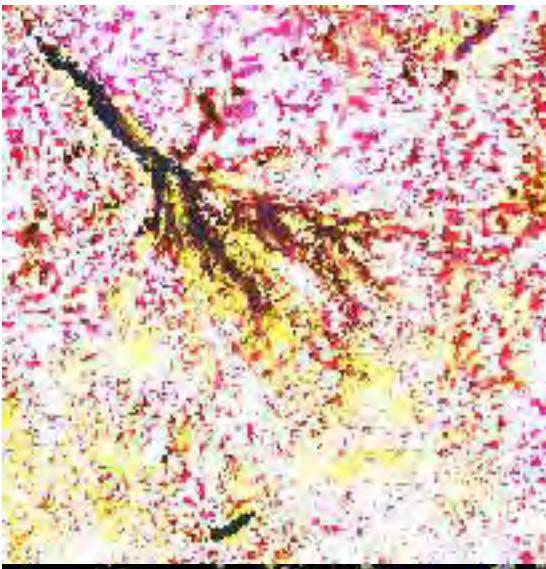


N  
100 Km

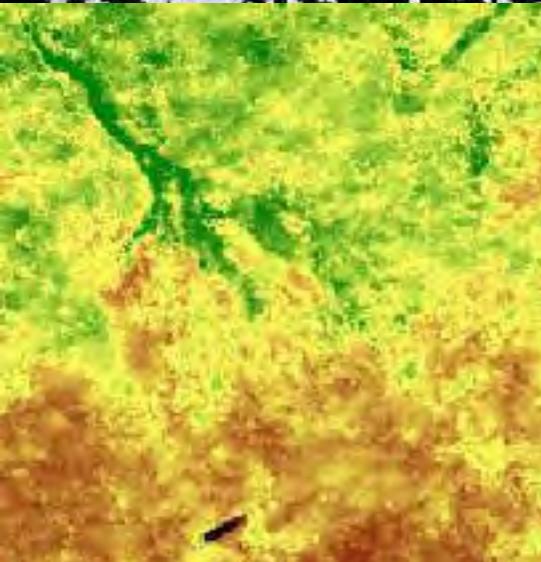
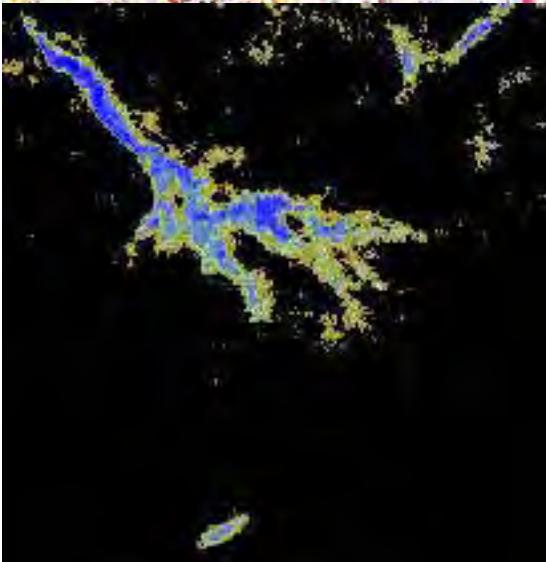
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

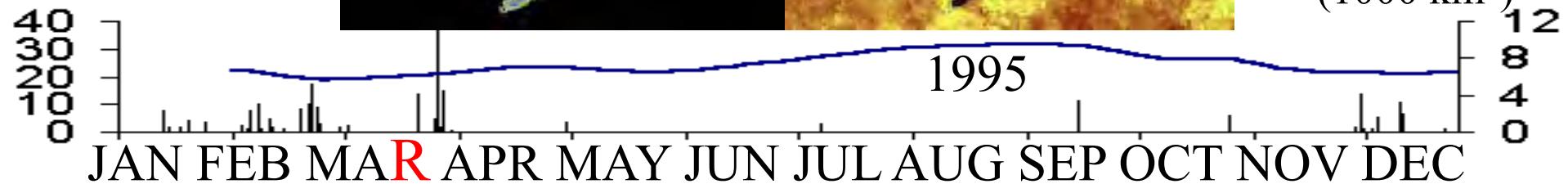
True  
colours



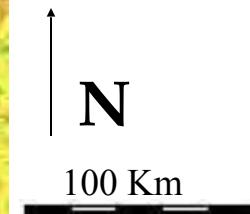
Water



Precipitation  
(mm)



Water area  
(1000 km<sup>2</sup>)



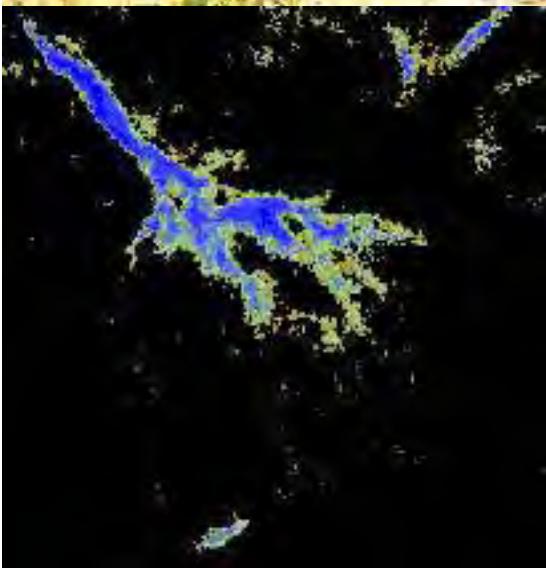
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

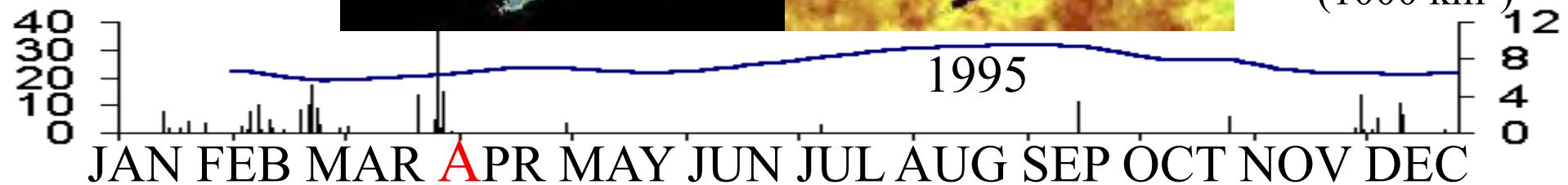
True  
colours



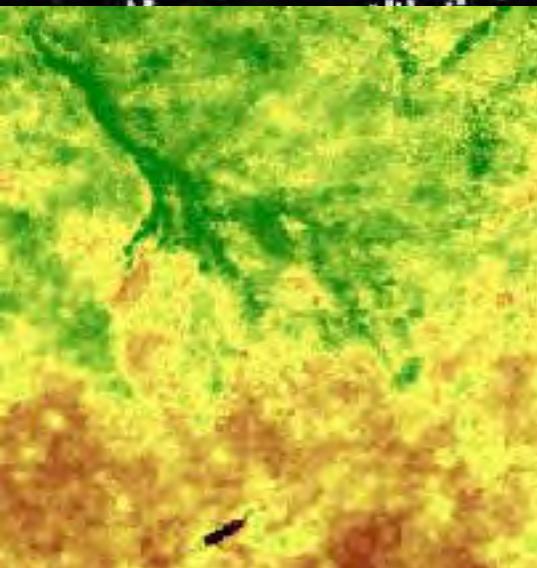
Water



Precipitation  
(mm)

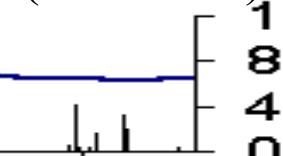


Clouds  
NDVI



N  
100 Km

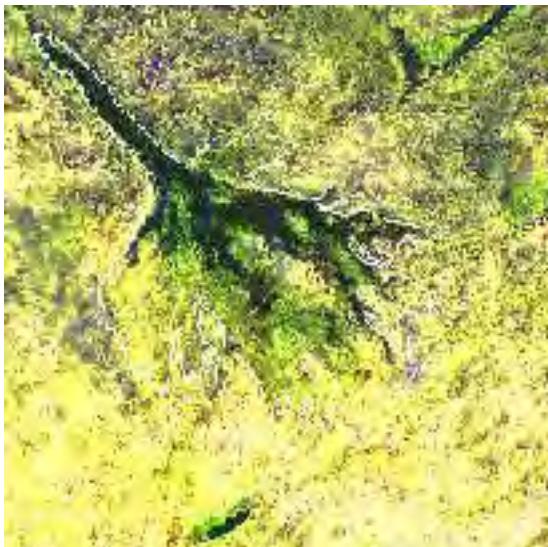
Water area  
(1000 km²)



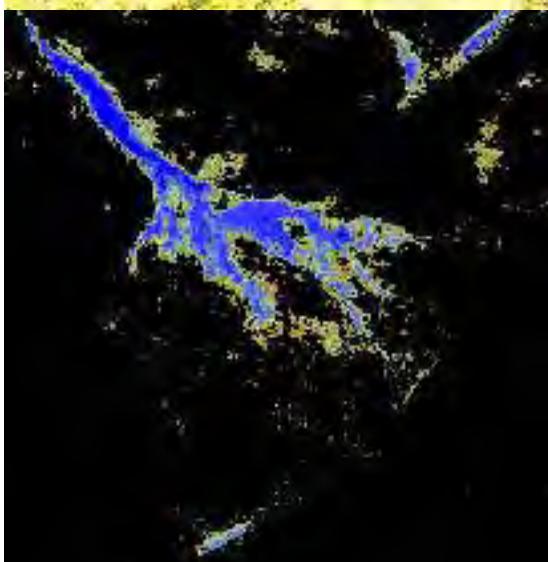
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

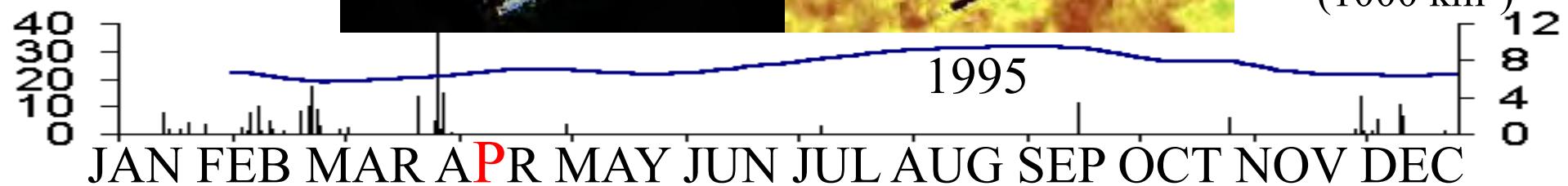
True  
colours



Water



Precipitation  
(mm)



Clouds

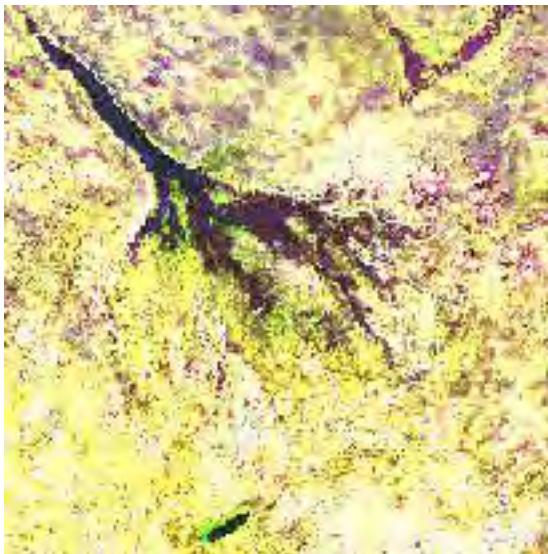
NDVI

N  
100 Km

# Okavango Delta, Botswana

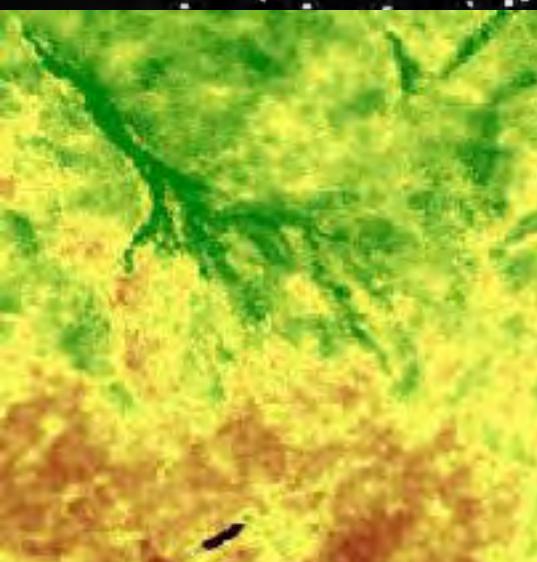
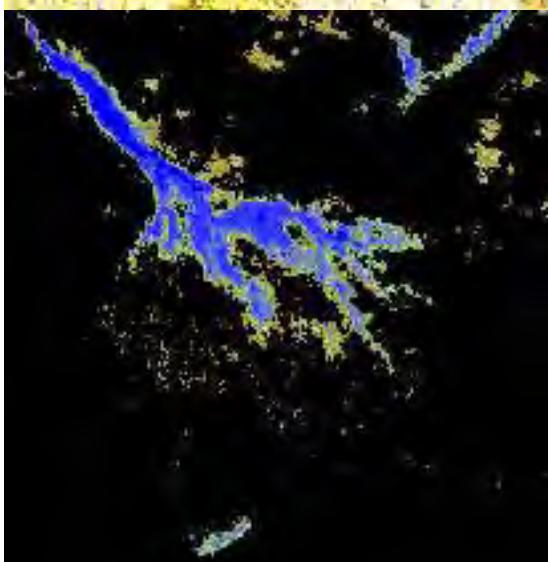
NOAA-  
AVHRR  
Images

True  
colours

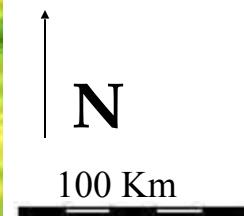
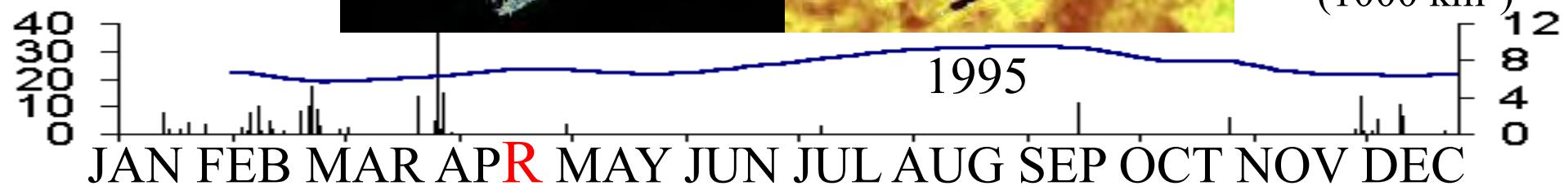


Clouds

Water



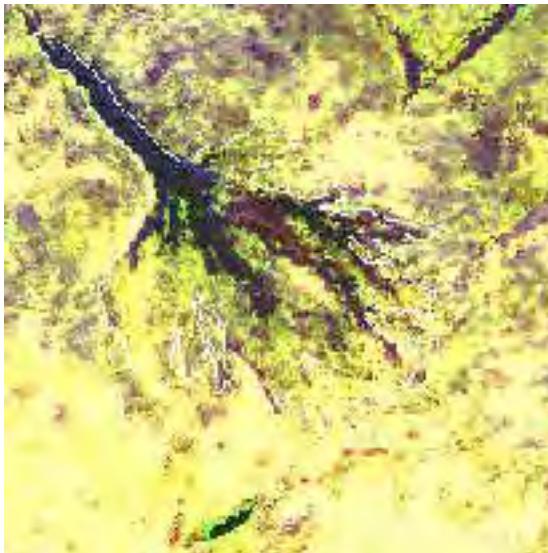
Precipitation  
(mm)



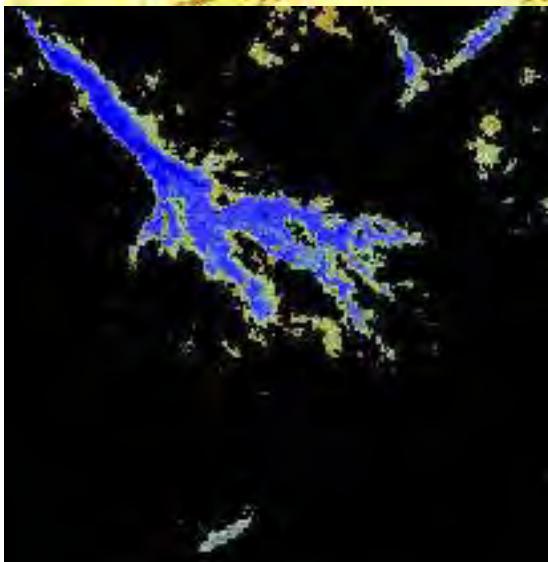
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

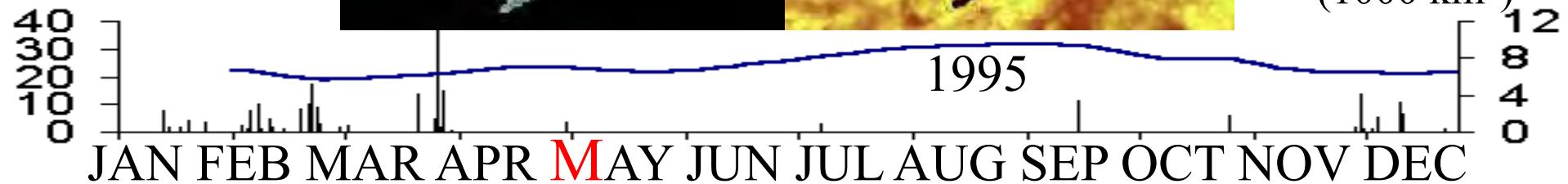
True  
colours



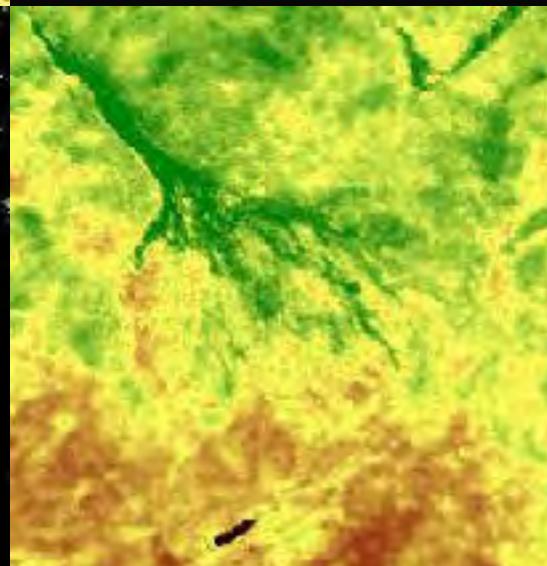
Water



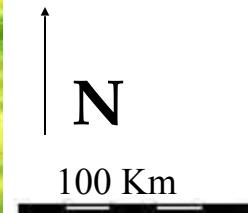
Precipitation  
(mm)



Clouds



NDVI



Water area  
(1000 km<sup>2</sup>)

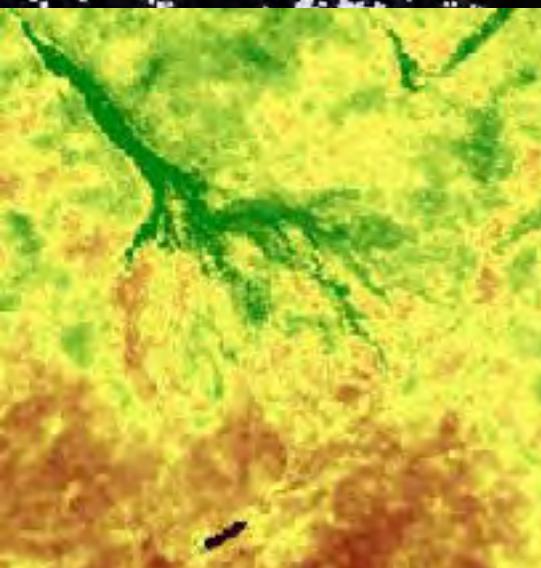
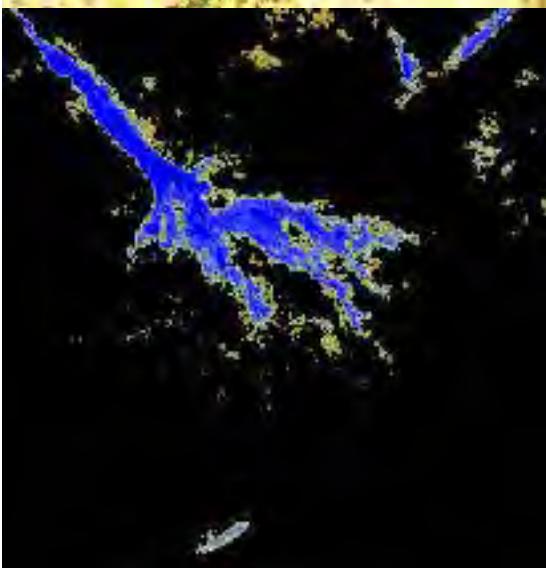
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

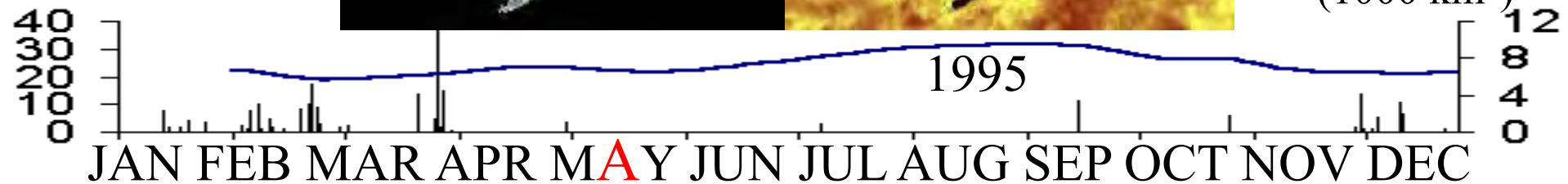
True  
colours



Water



Precipitation  
(mm)



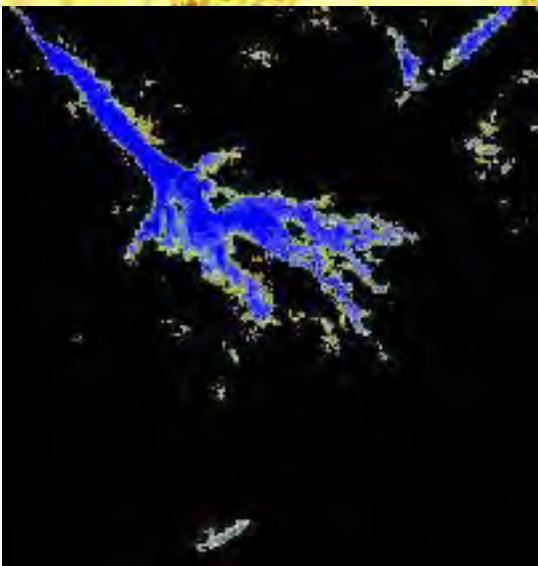
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

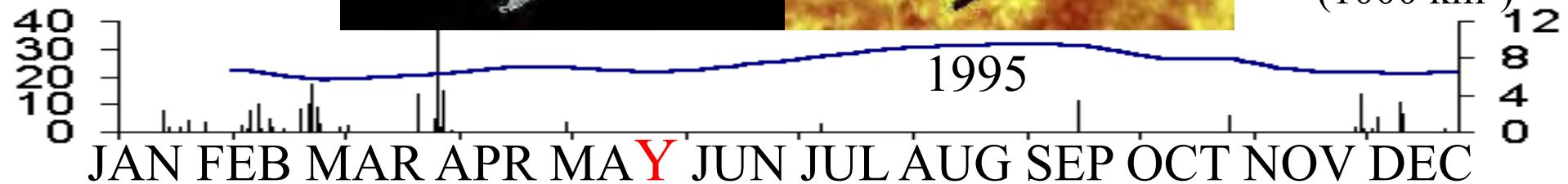
True  
colours



Water



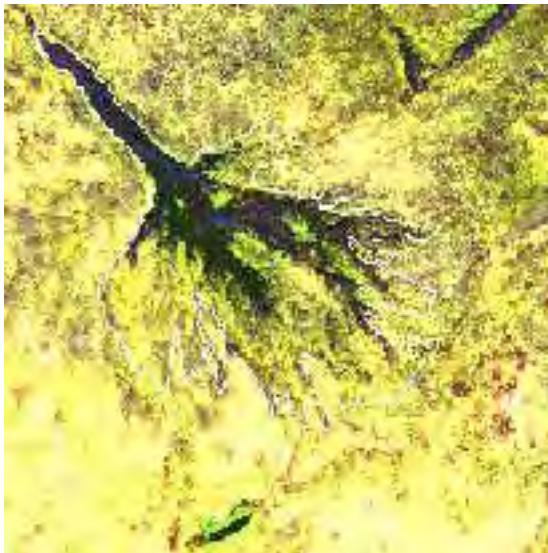
Precipitation  
(mm)



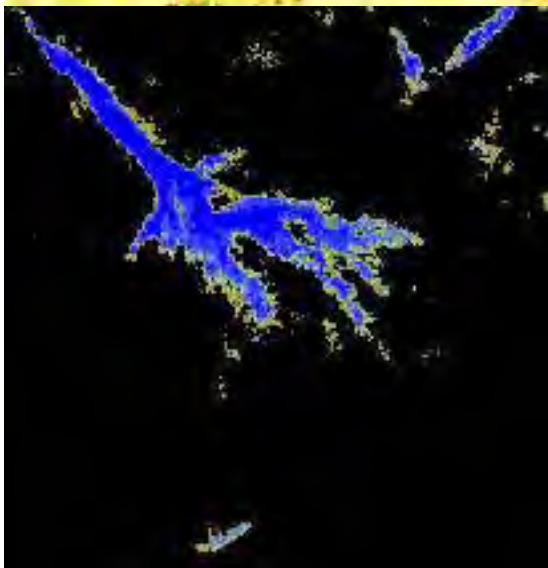
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

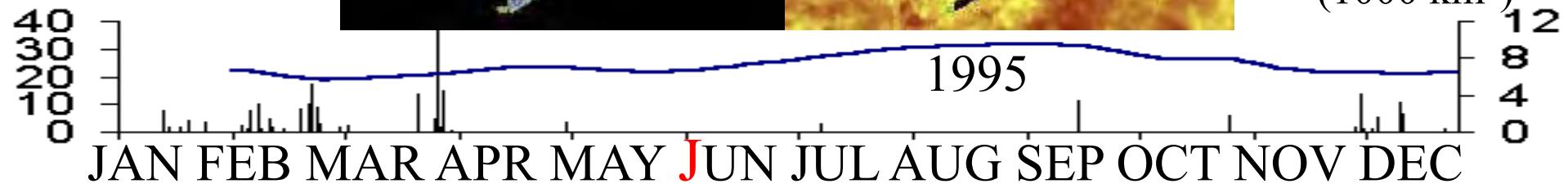
True  
colours



Water



Precipitation  
(mm)



Clouds

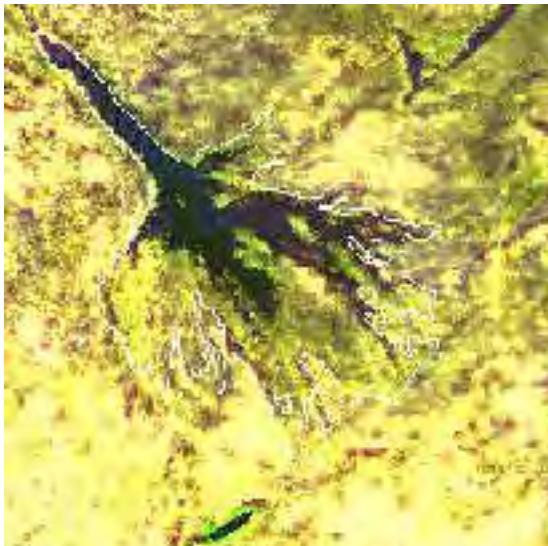
NDVI

N  
100 Km

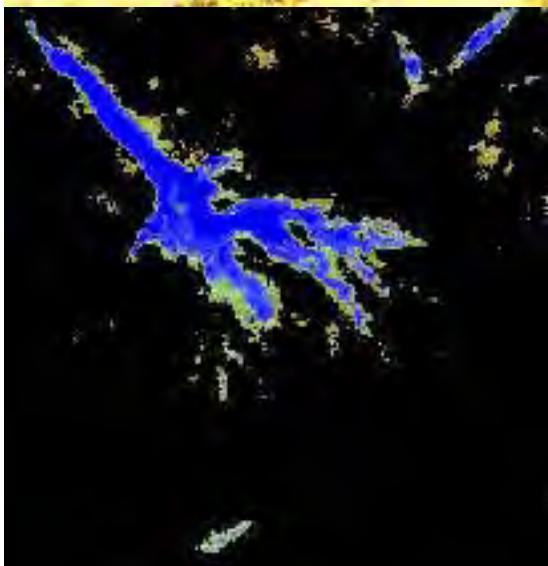
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

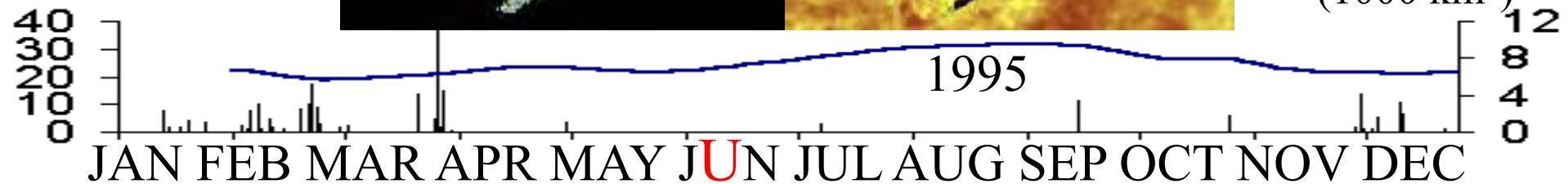
True  
colours



Water



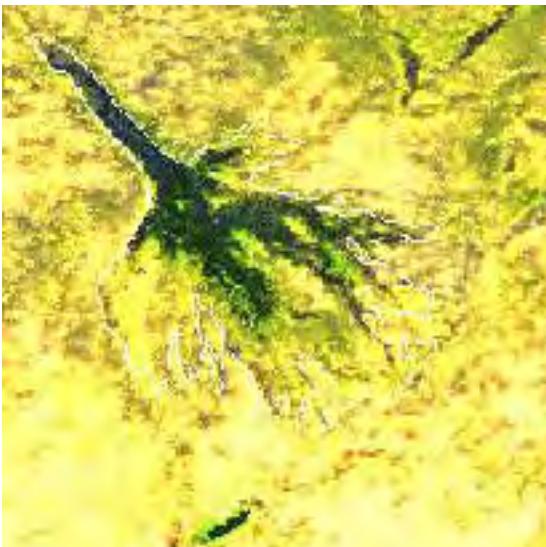
Precipitation  
(mm)



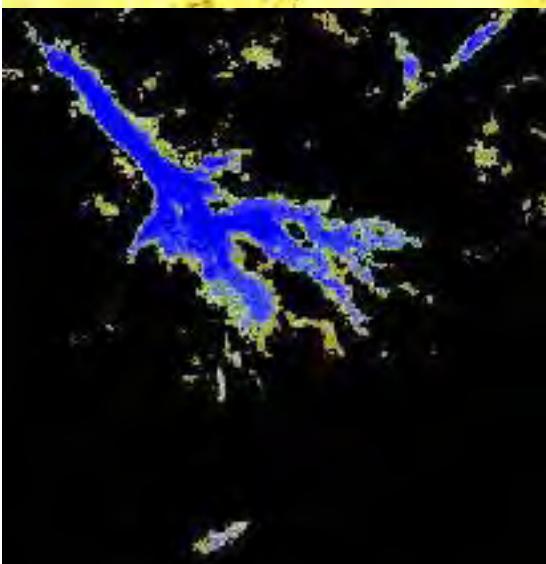
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

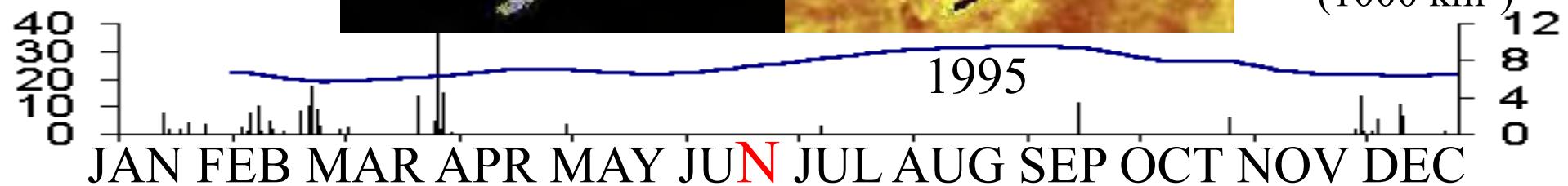
True  
colours



Water



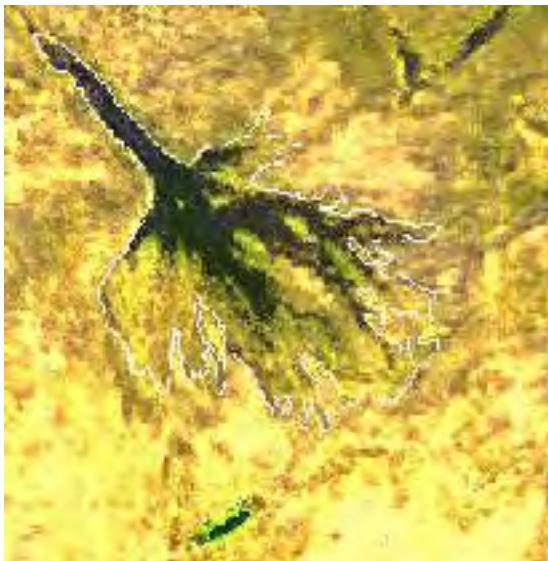
Precipitation  
(mm)



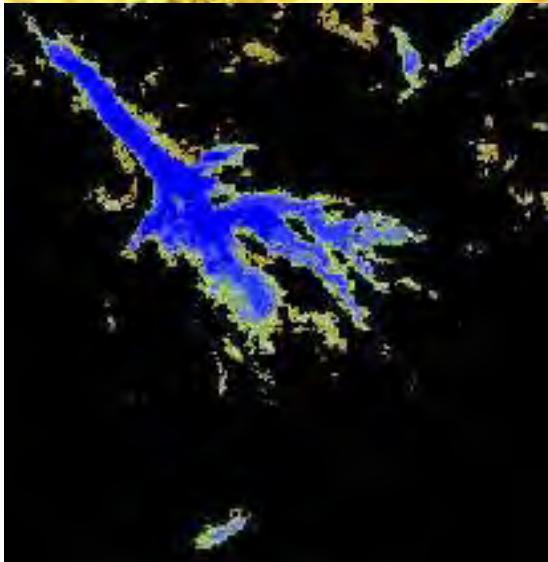
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

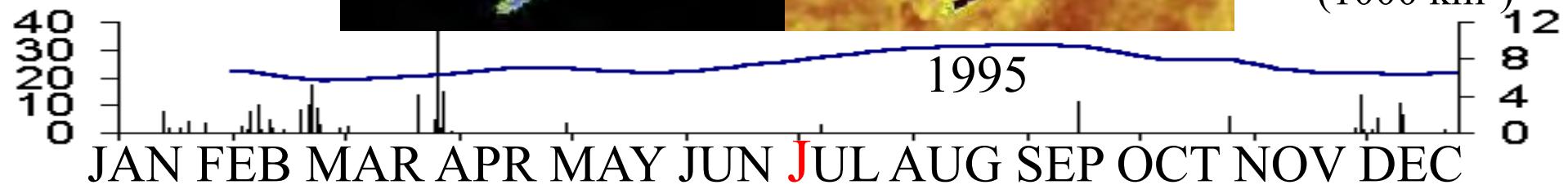
True  
colours



Water



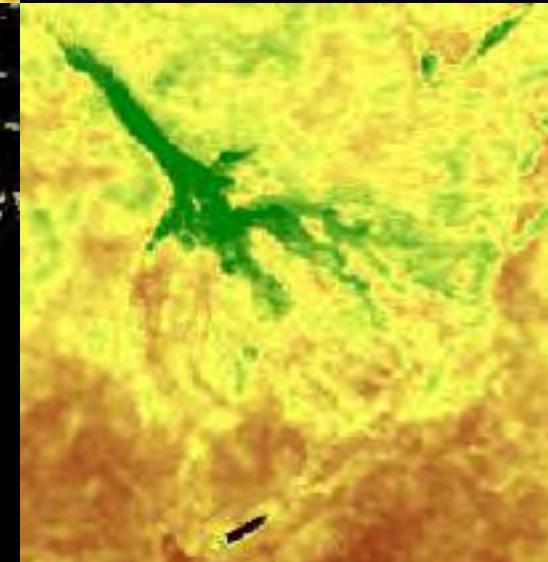
Precipitation  
(mm)



Clouds



NDVI



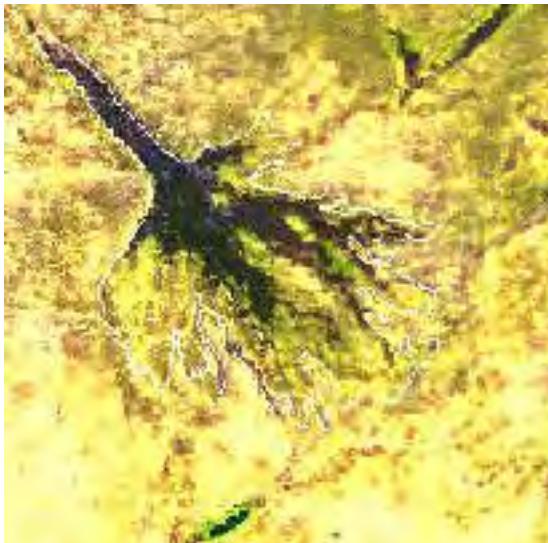
N  
100 Km

Water area  
(1000 km<sup>2</sup>)

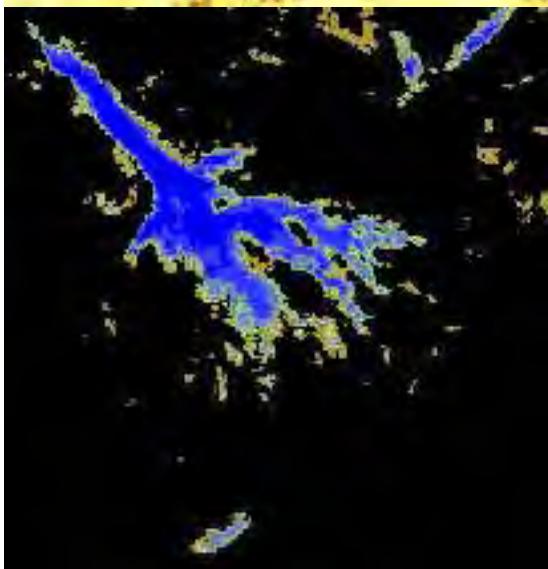
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

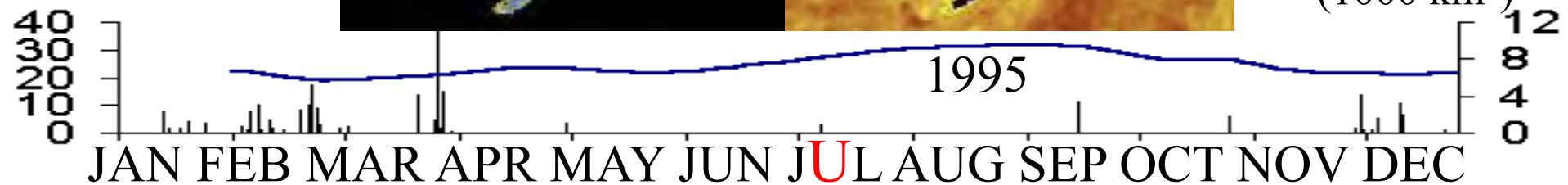
True  
colours



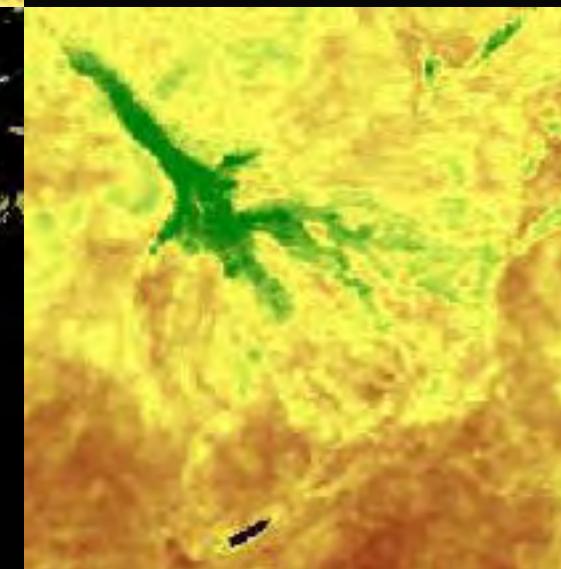
Water



Precipitation  
(mm)



Clouds



NDVI

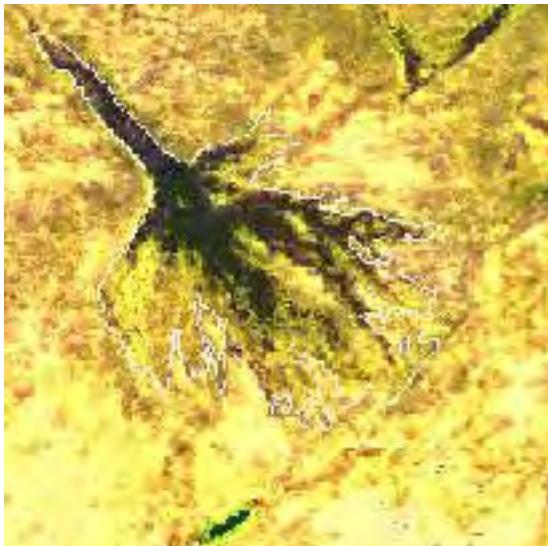
N  
100 Km

Water area  
(1000 km<sup>2</sup>)

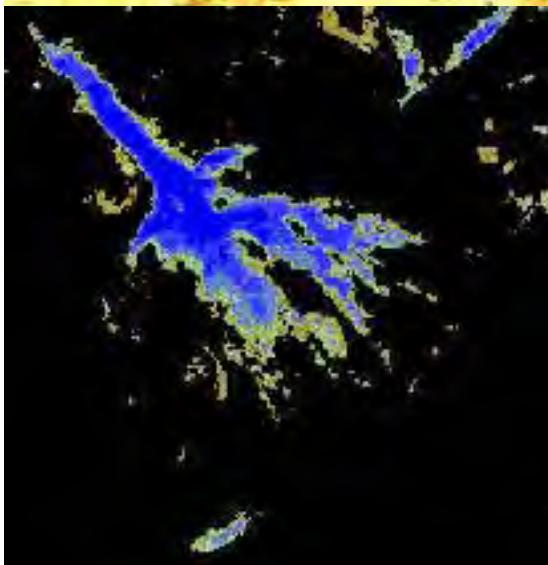
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



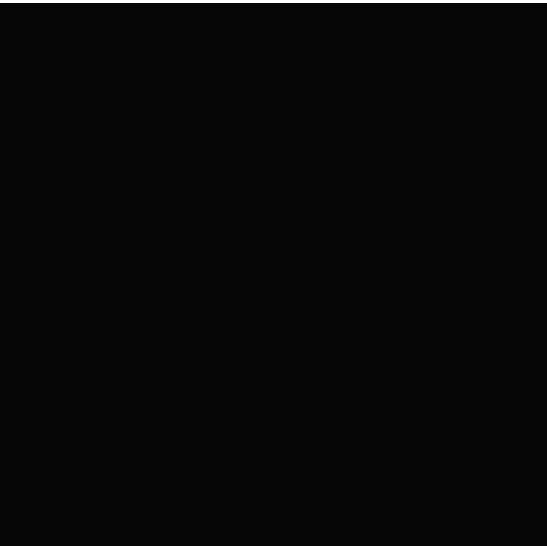
Water



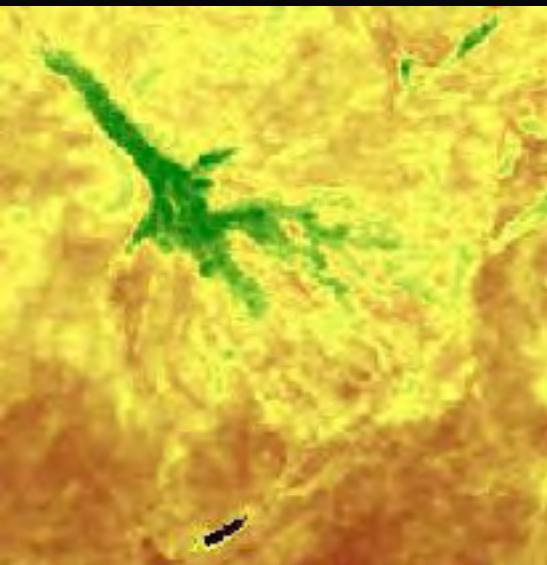
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

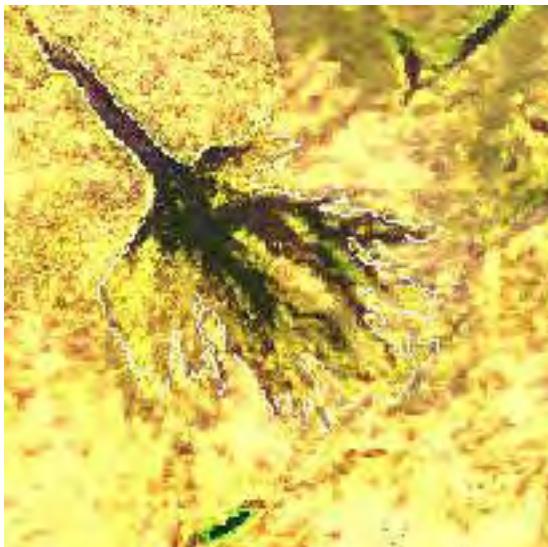
Water area  
(1000 km²)

1995

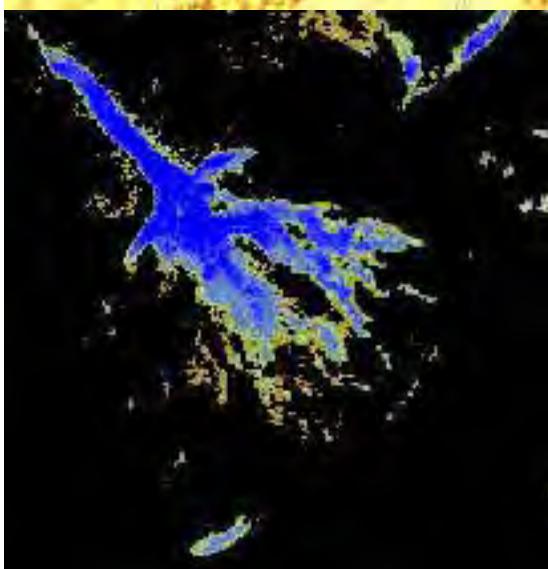
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

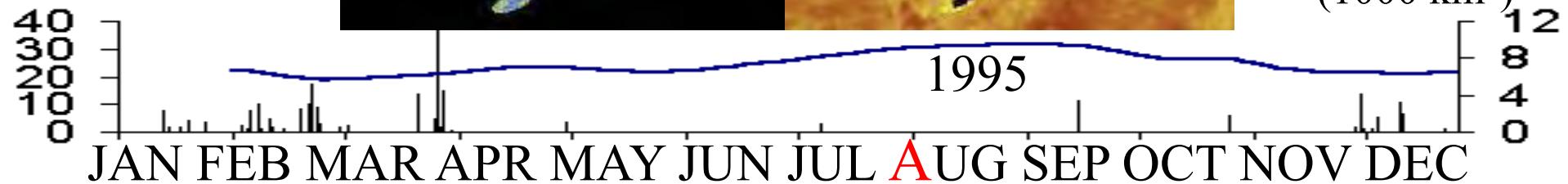
True  
colours



Water



Precipitation  
(mm)



Clouds

NDVI

N  
100 Km

Water area  
(1000 km<sup>2</sup>)

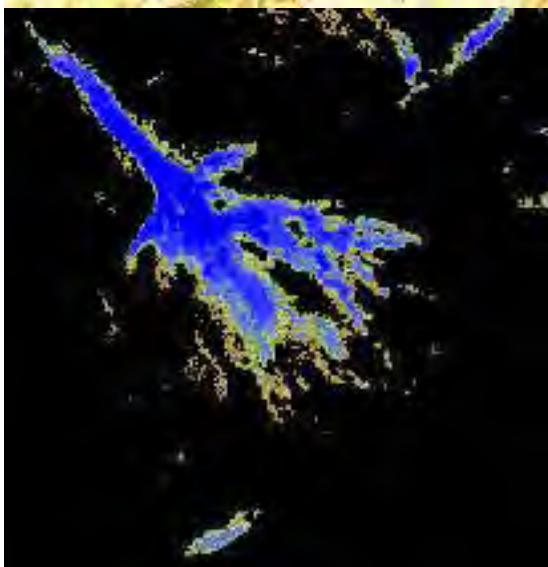
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

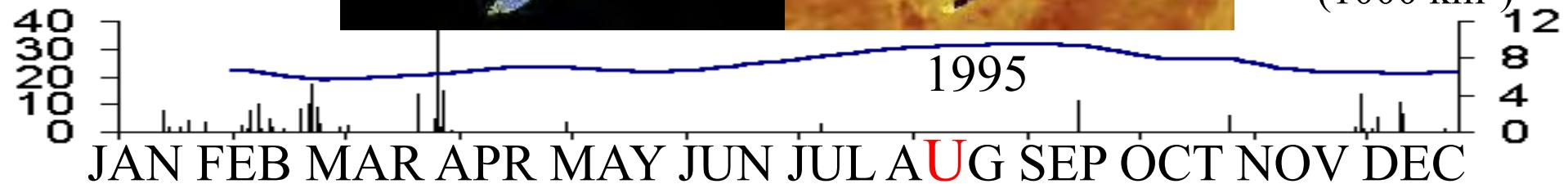
True  
colours



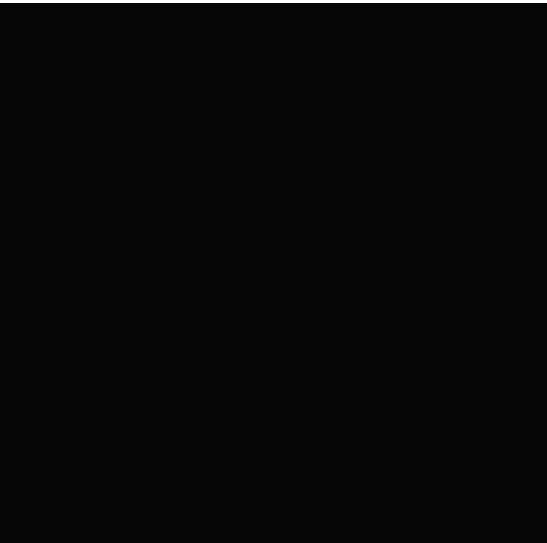
Water



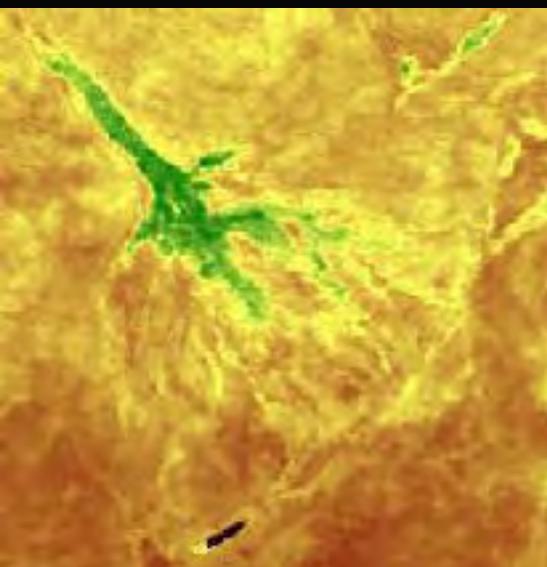
Precipitation  
(mm)



Clouds



NDVI



N  
↑

100 Km

Water area  
(1000 km²)

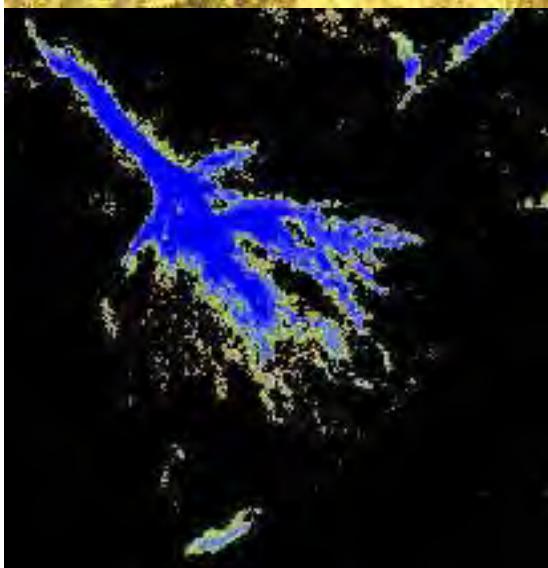
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

True  
colours



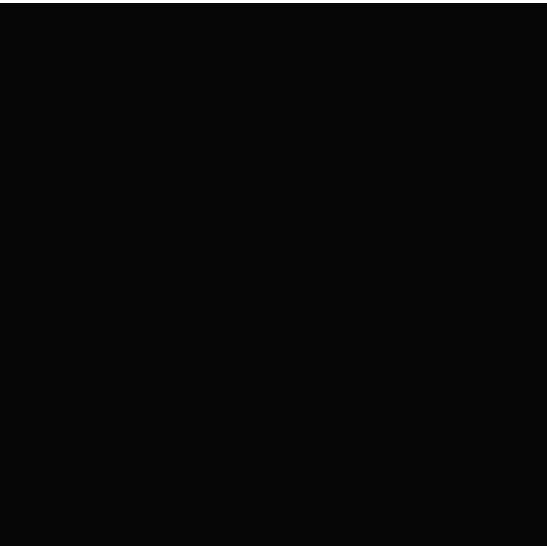
Water



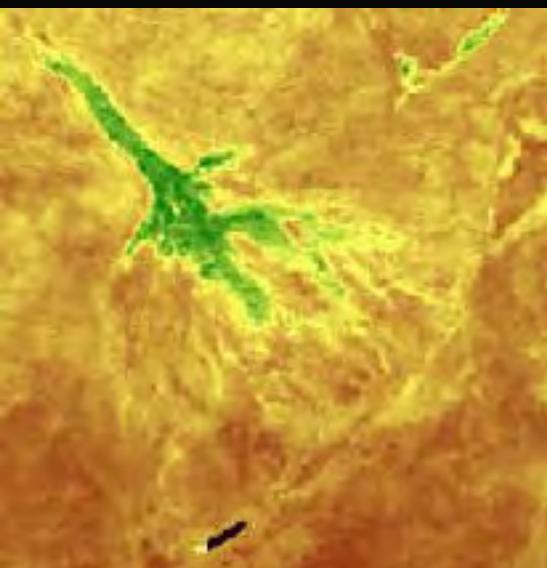
Precipitation  
(mm)



Clouds



NDVI



N

100 Km

Water area  
(1000 km²)

1995

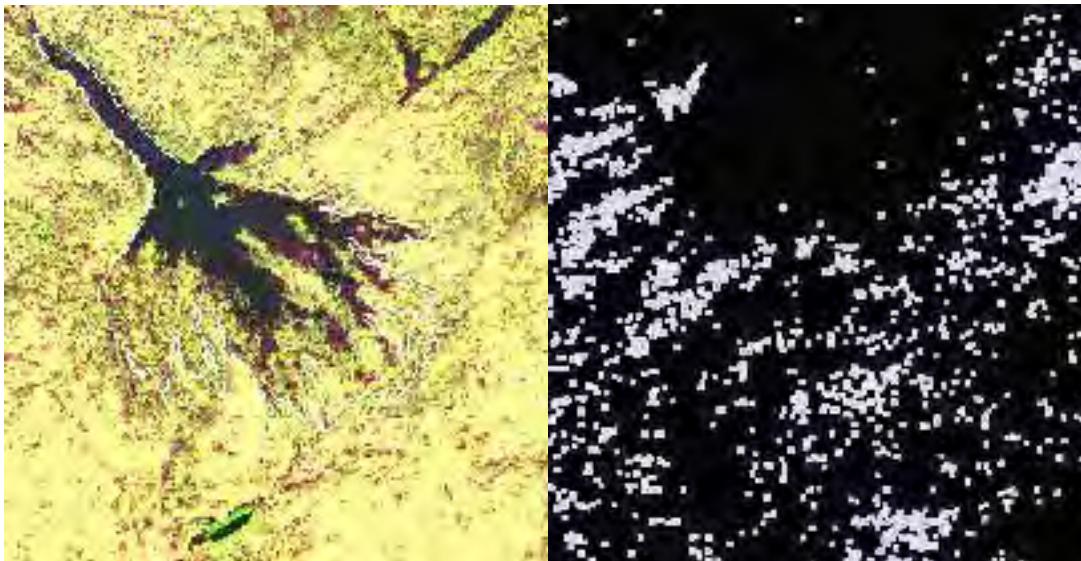
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JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

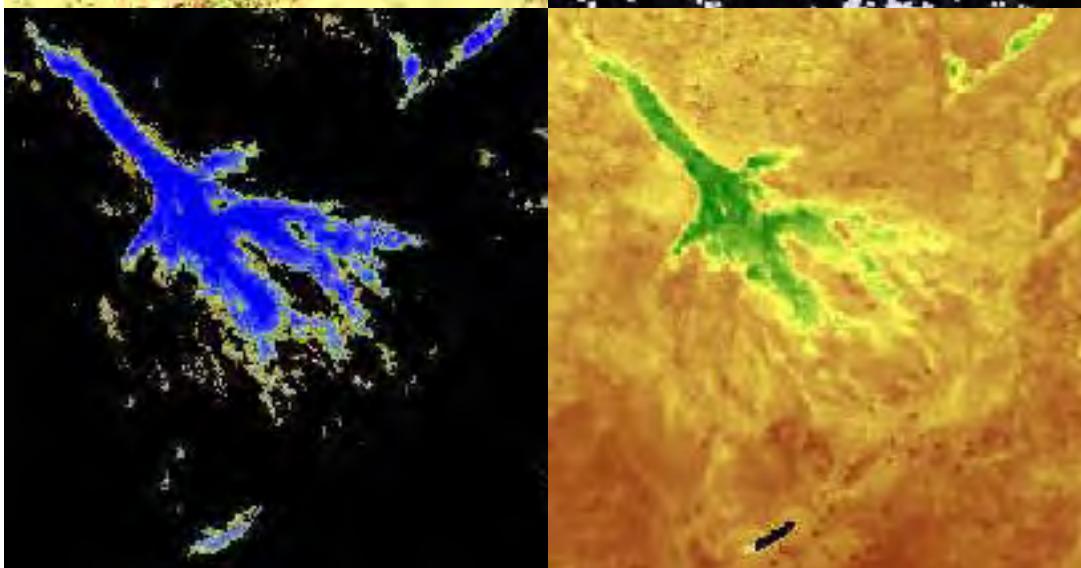
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

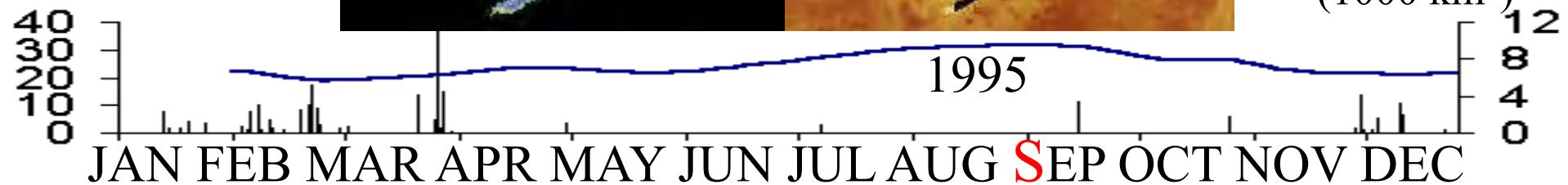
True  
colours



Water



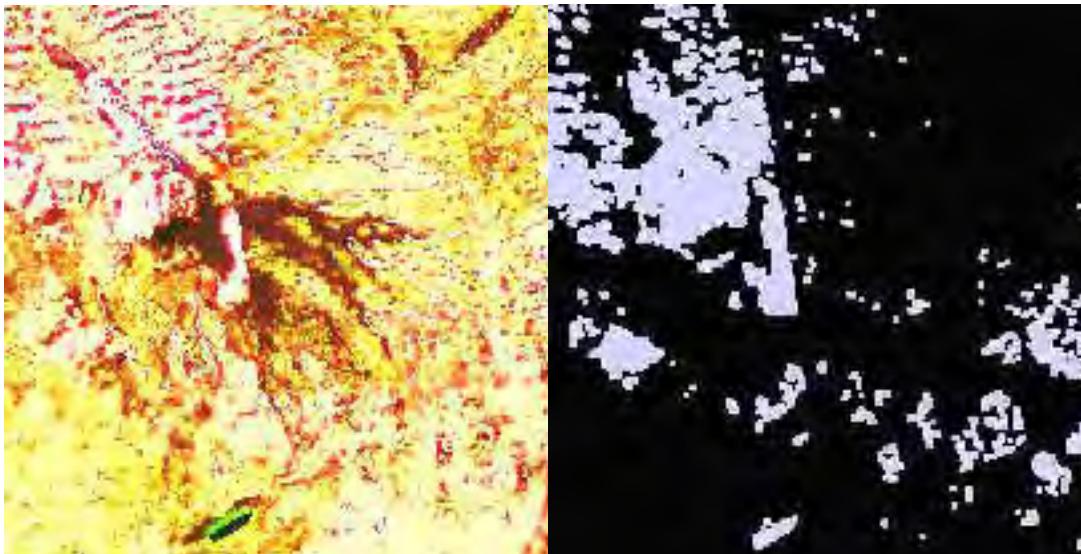
Precipitation  
(mm)



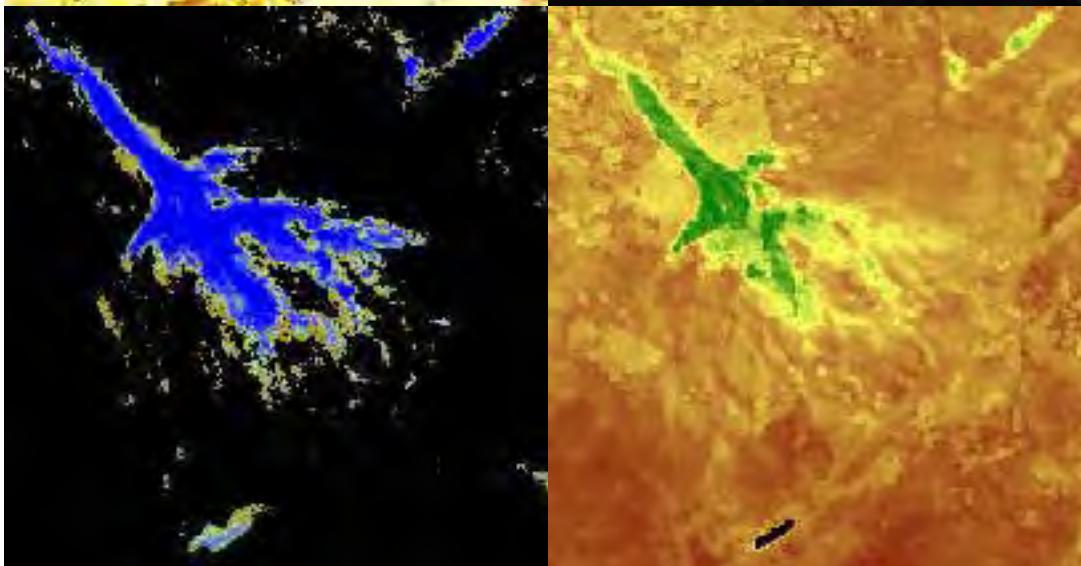
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

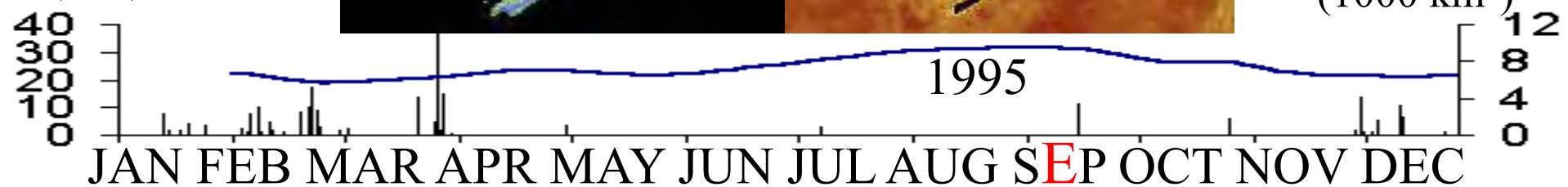
True  
colours



Water



Precipitation  
(mm)



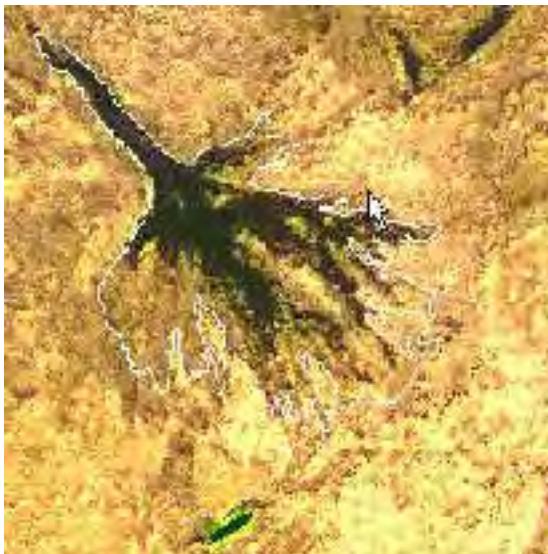
Clouds  
NDVI

N  
100 Km  
Water area  
(1000 km²)

# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

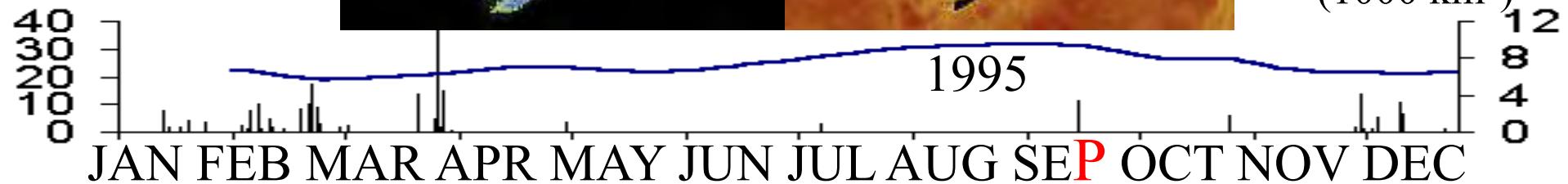
True  
colours



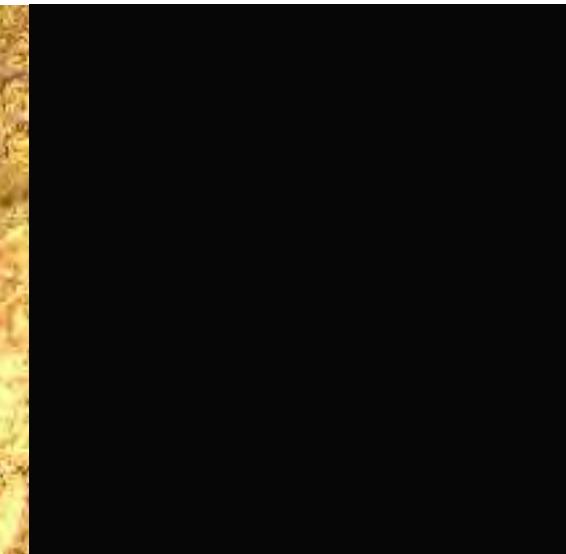
Water



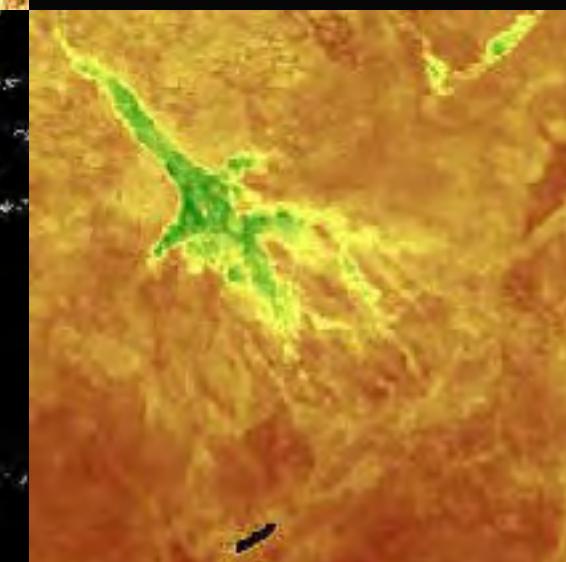
Precipitation  
(mm)



Clouds



NDVI



N  
100 Km

Water area  
(1000 km²)

# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

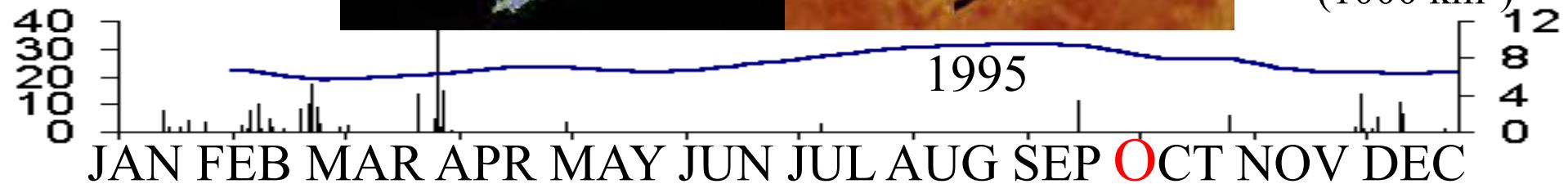
True  
colours



Water



Precipitation  
(mm)



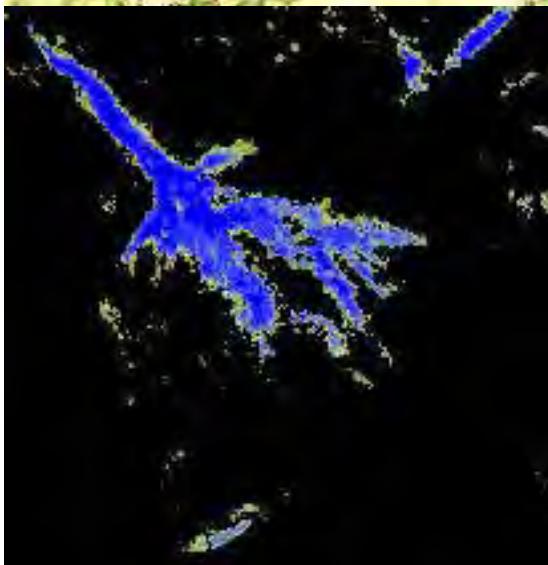
# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

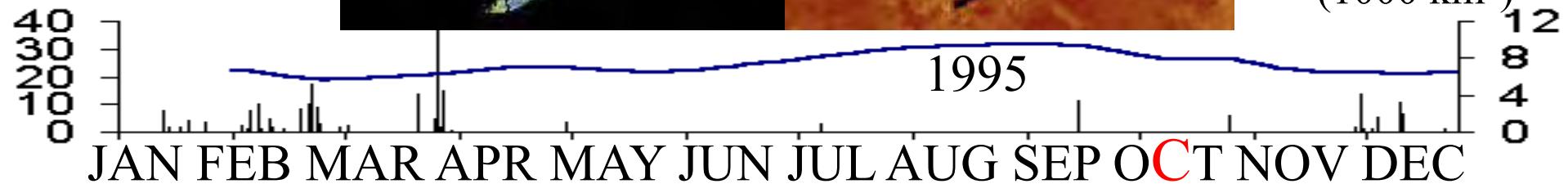
True  
colours



Water



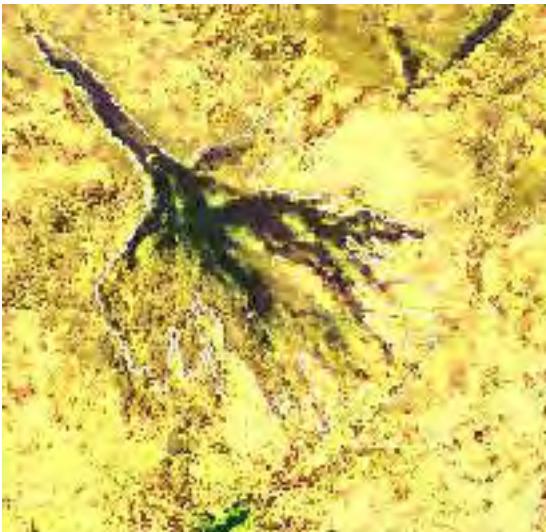
Precipitation  
(mm)



# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

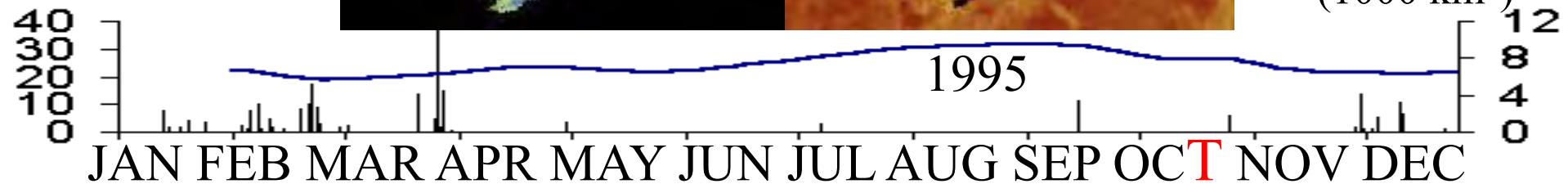
True  
colours



Water

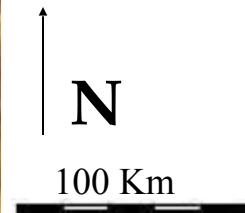


Precipitation  
(mm)



Clouds

NDVI



# Okavango Delta, Botswana

NOAA-  
AVHRR  
Images

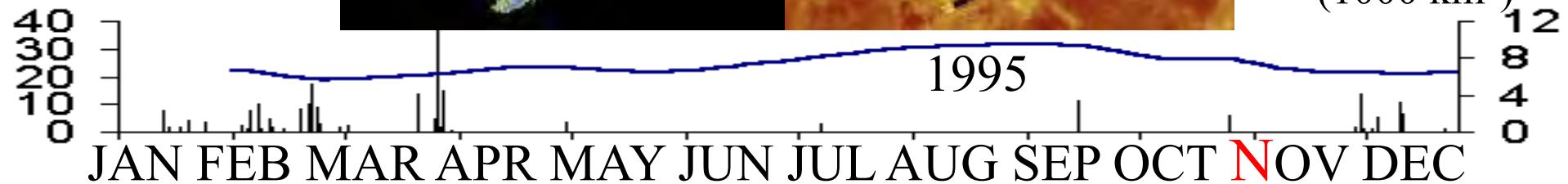
True  
colours



Water



Precipitation  
(mm)



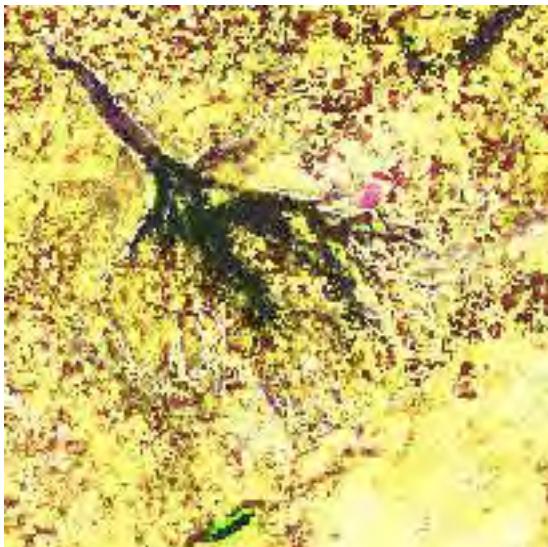
Clouds

NDVI

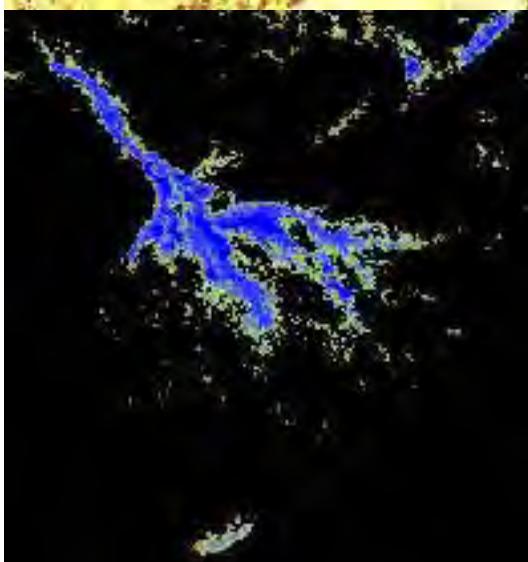
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NOAA-  
AVHRR  
Images

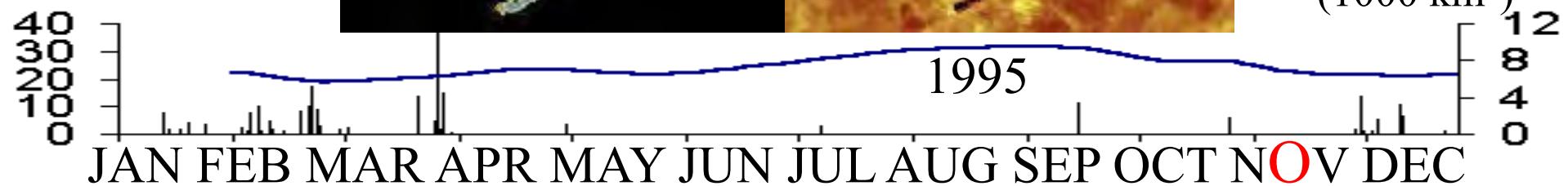
True  
colours



Water



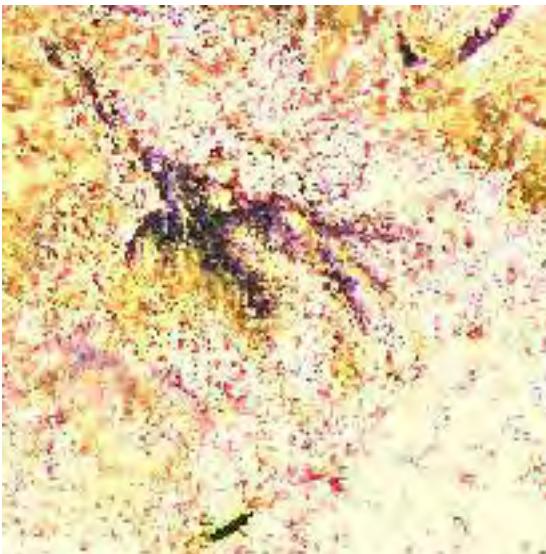
Precipitation  
(mm)



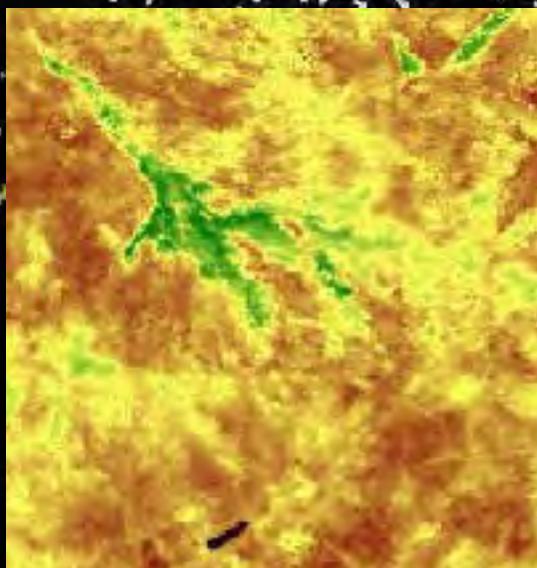
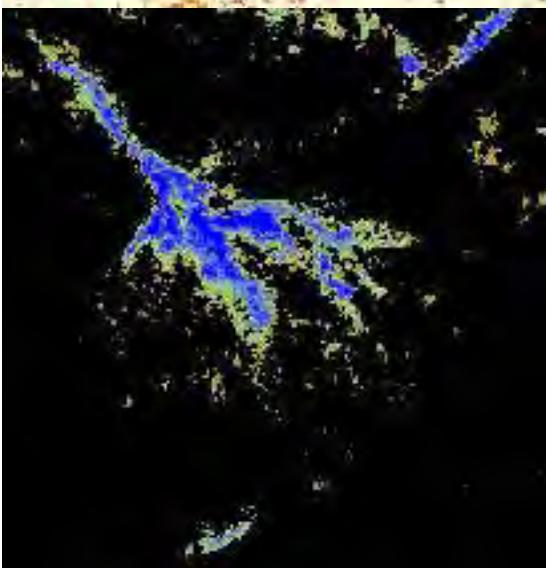
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Images

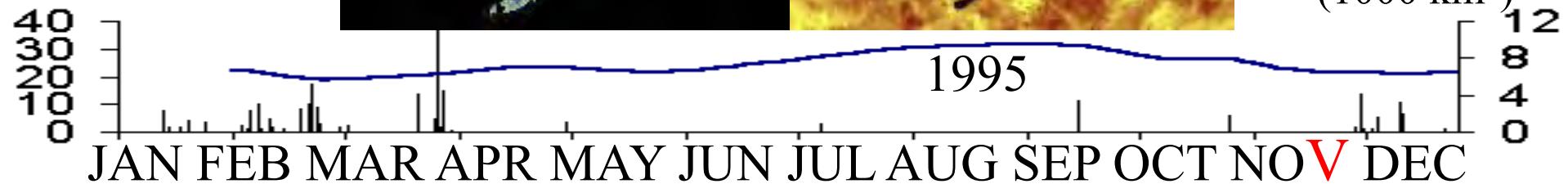
True  
colours



Water



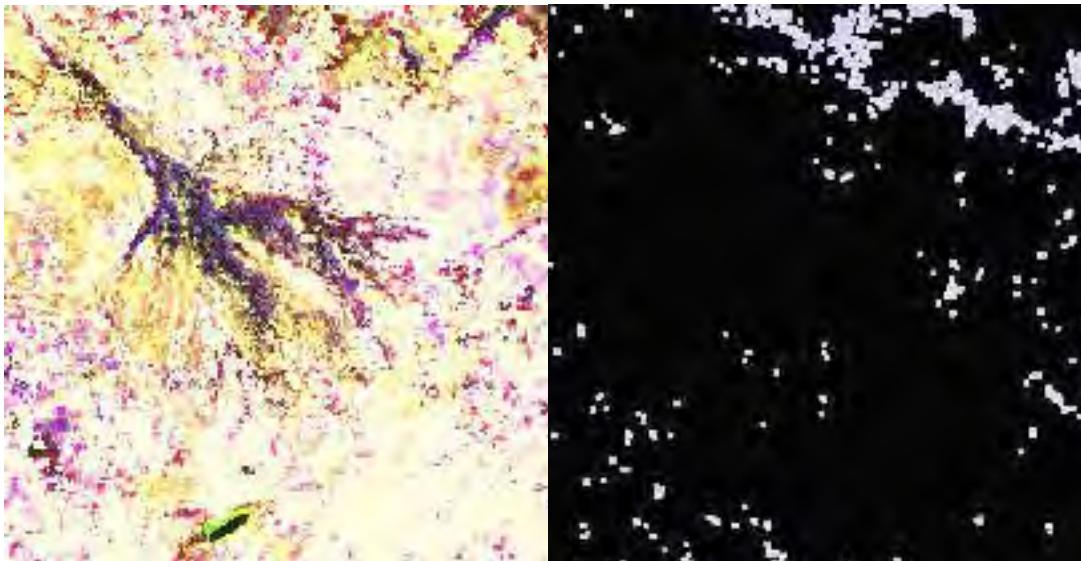
Precipitation  
(mm)



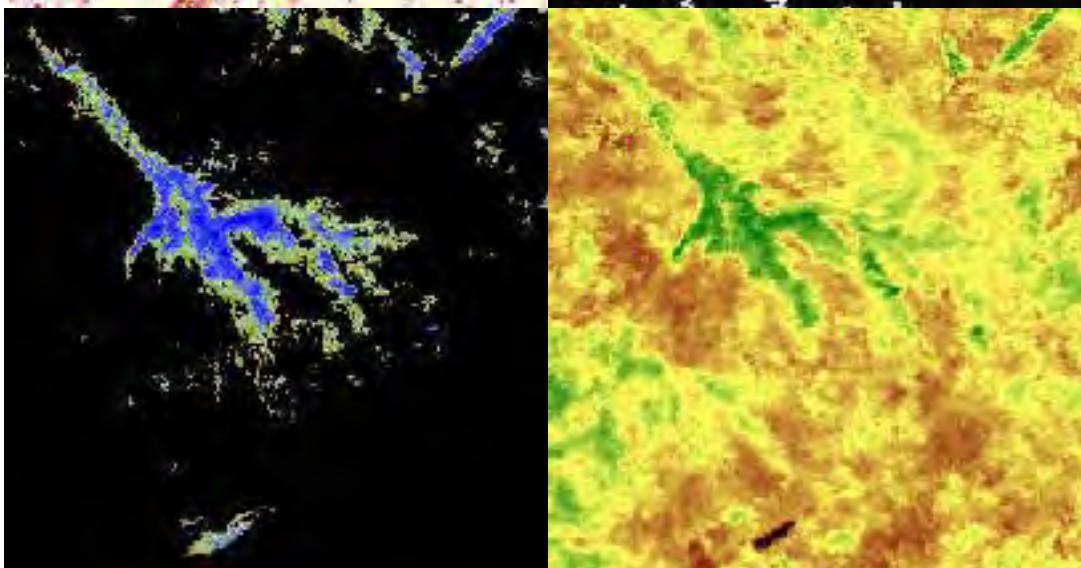
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NOAA-  
AVHRR  
Images

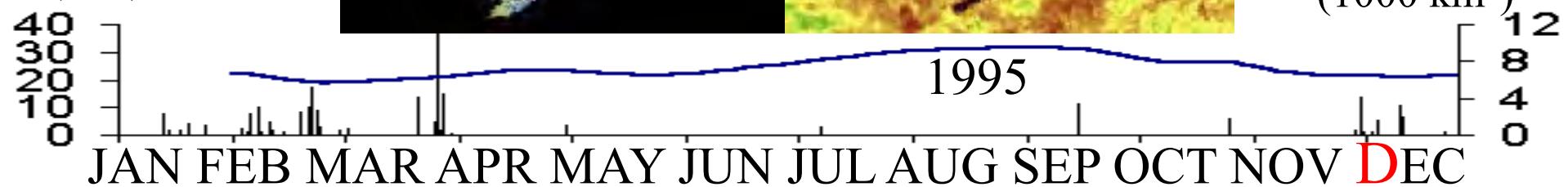
True  
colours



Water



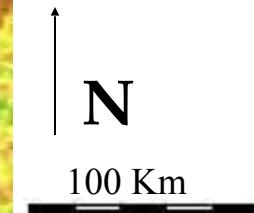
Precipitation  
(mm)



1995

Clouds

NDVI



Water area  
(1000 km<sup>2</sup>)

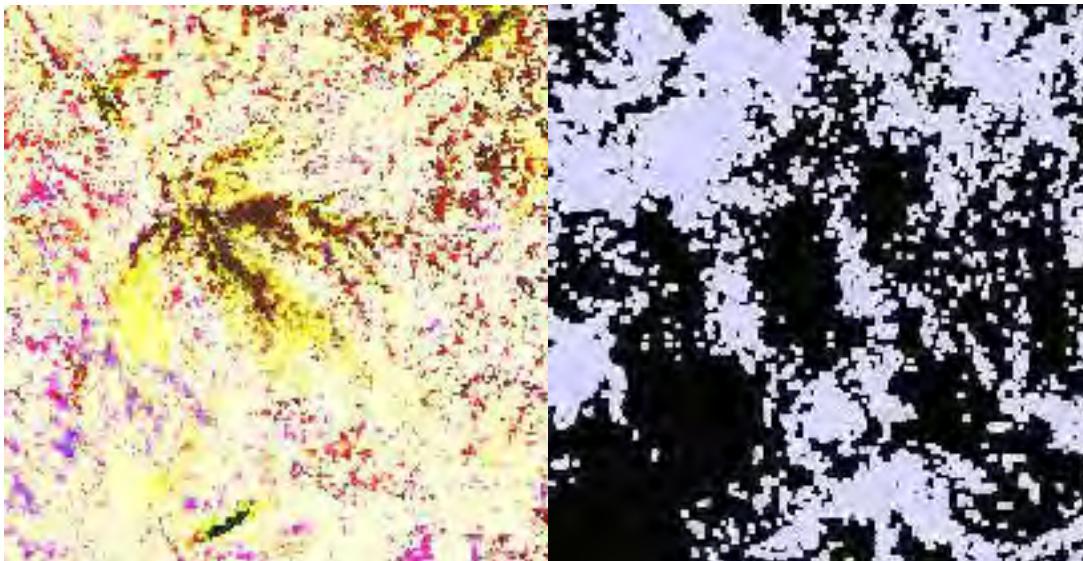
12  
8  
4  
0

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

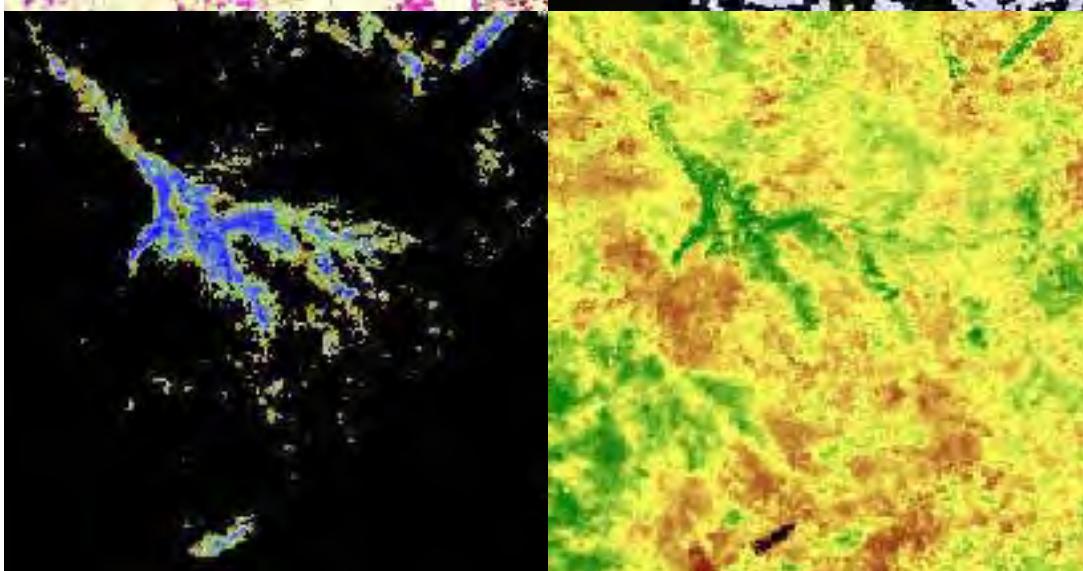
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NOAA-  
AVHRR  
Images

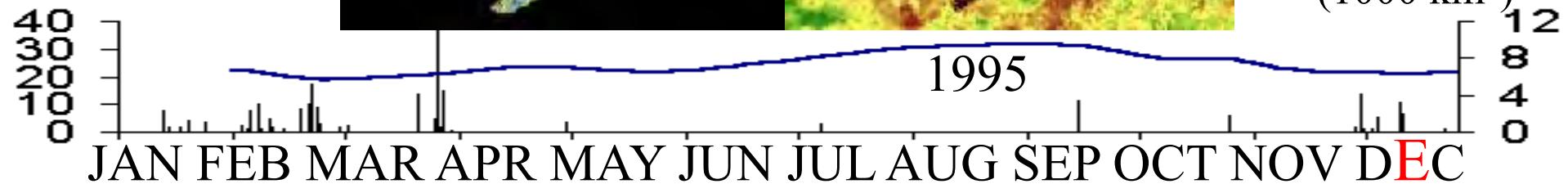
True  
colours



Water



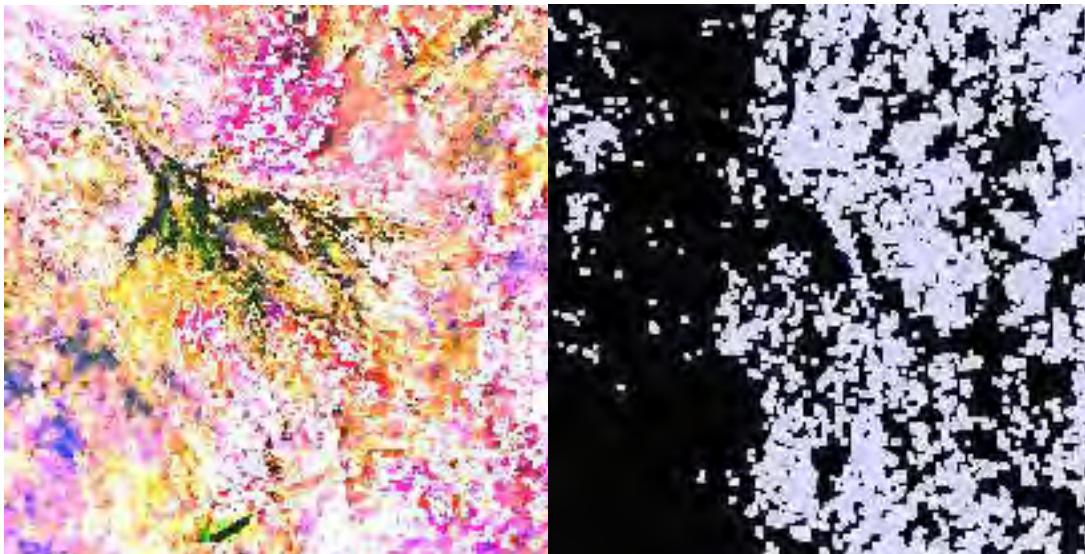
Precipitation  
(mm)



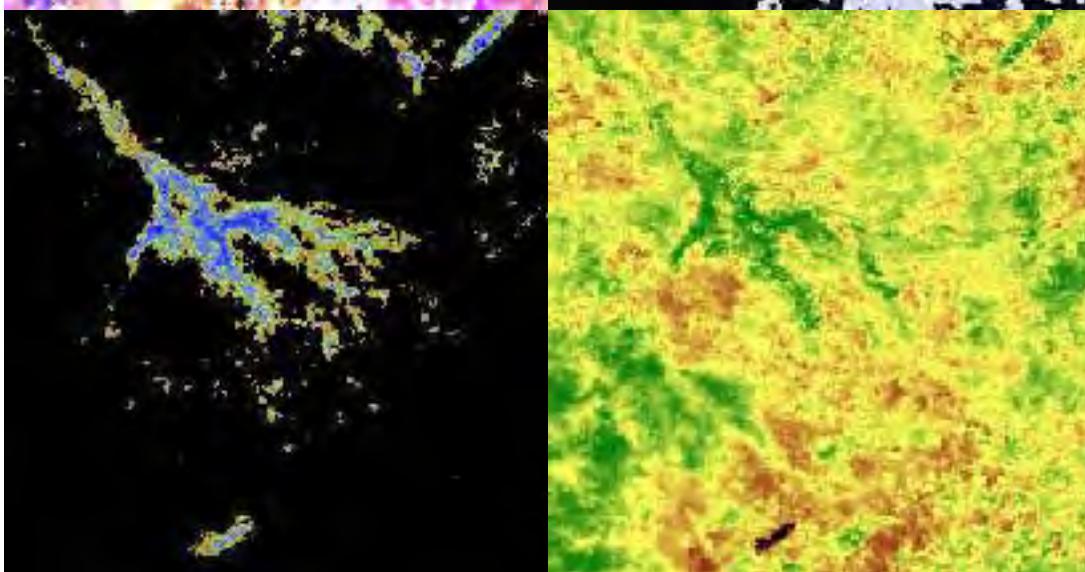
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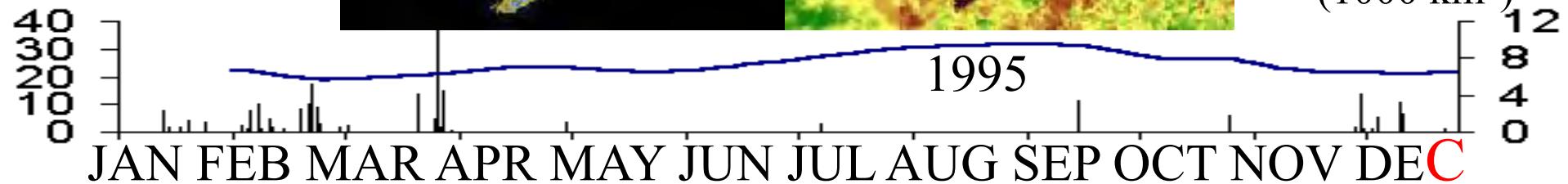
True  
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Water



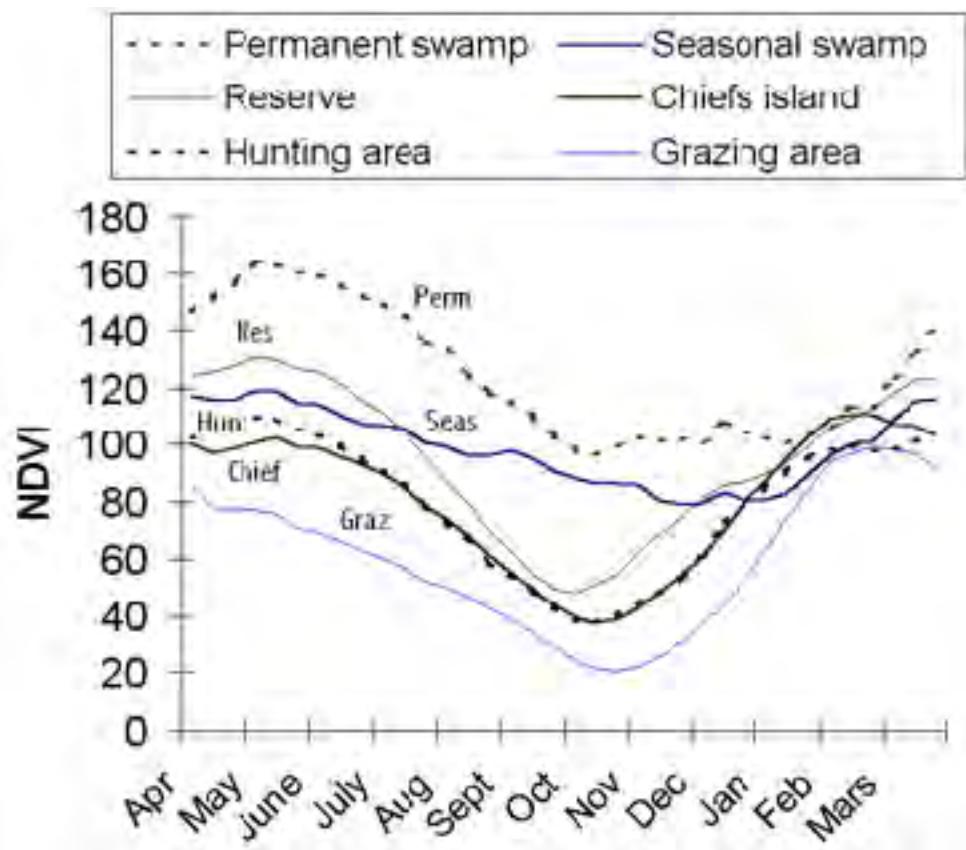
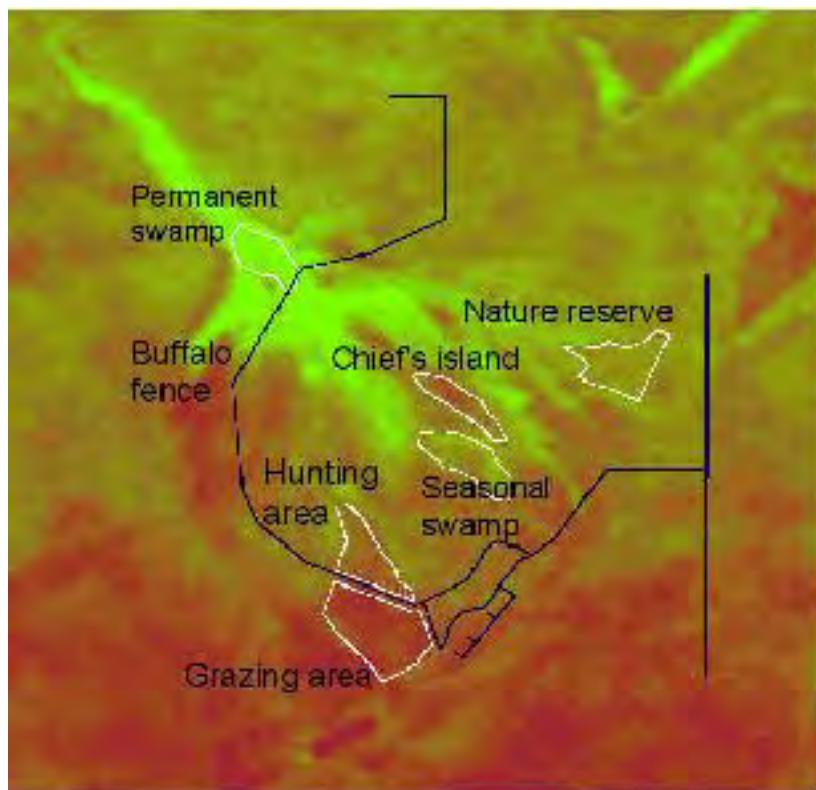
Precipitation  
(mm)



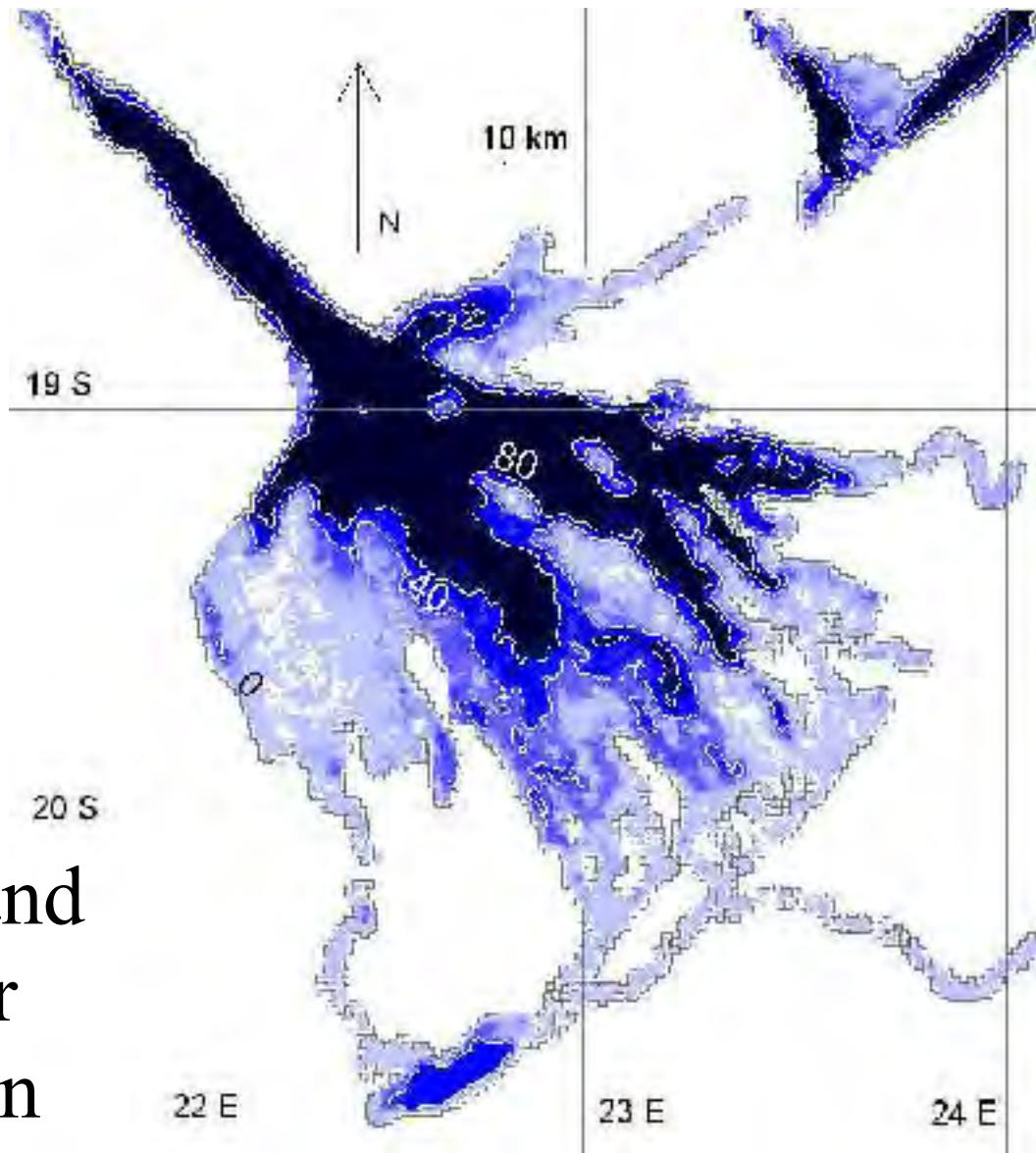
# Results



# Spatial and temporal variation of NDVI



# Percent of time with water cover





## Summary of results:

The study confirms the anecdotal knowledge 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, ground truth data will be collected later this year (partly in cooperation with SAFARI)



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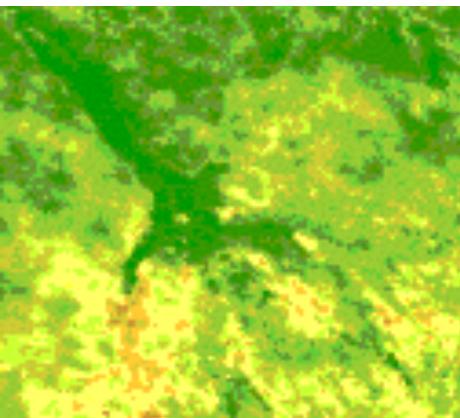
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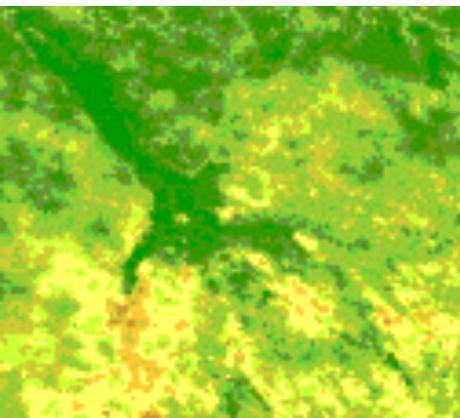
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# Conclusions

The following conclusions were drawn:

• The first conclusion is that...

• The second conclusion is that...

• The third conclusion is that...

• The fourth conclusion is that...

• The fifth conclusion is that...

• The sixth conclusion is that...

• The seventh conclusion is that...

• The eighth conclusion is that...

• The ninth conclusion is that...

• The tenth conclusion is that...

• The eleventh conclusion is that...

• The twelfth conclusion is that...

• The thirteenth conclusion is that...

• The fourteenth conclusion is that...

• The fifteenth conclusion is that...

• The sixteenth conclusion is that...

• The seventeenth conclusion is that...

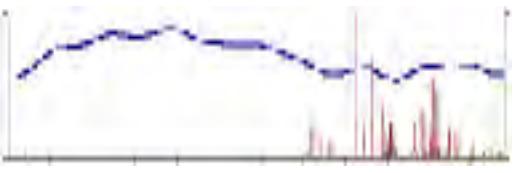
• The eighteenth conclusion is that...



## Conclusions:

*tautologico*

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

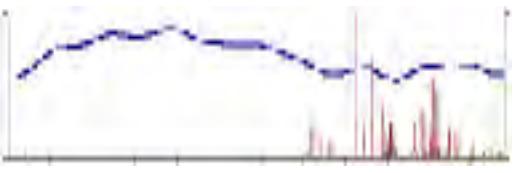
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tautologico  
for a

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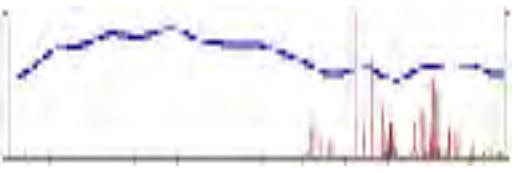
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tautologicoa

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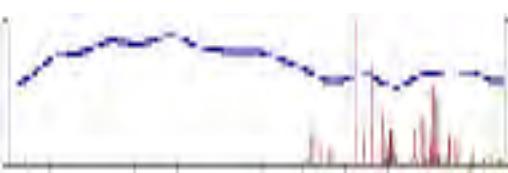
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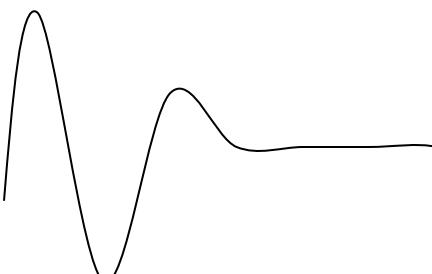
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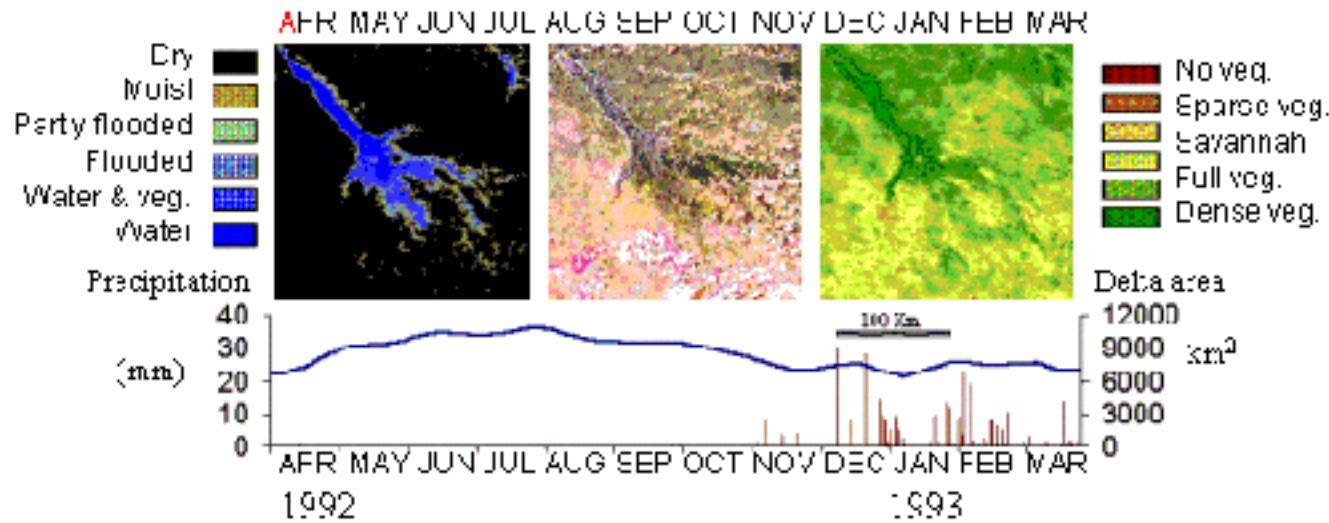


lack of sufficient *in situ* assessment of the acc

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

The lack and access of (base line), prevents robust conclusions on the geophysiological integrity of the Delta

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](http://www.geoinformatik.geo.uu.se/forskning)

(English translation in the pipe line)