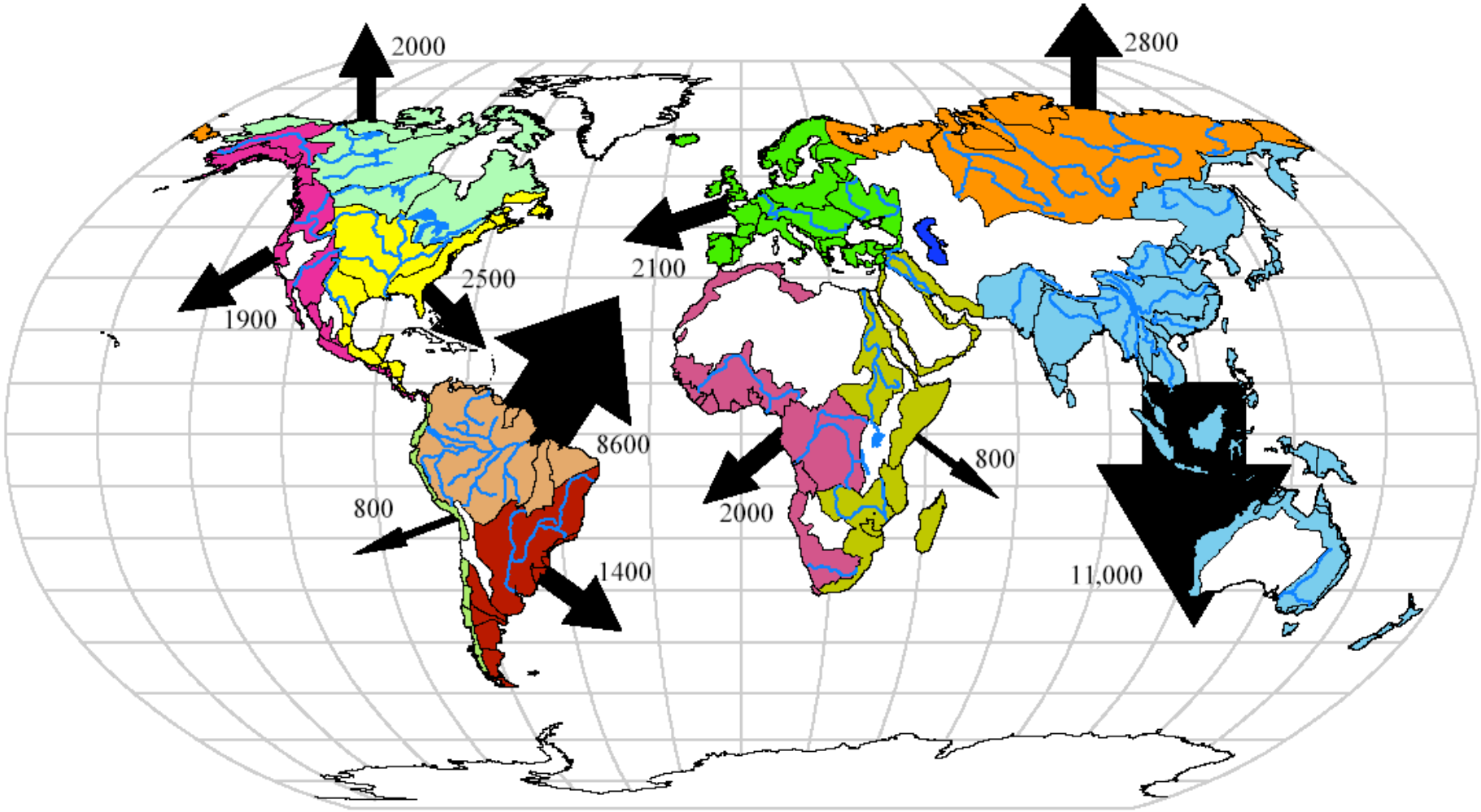
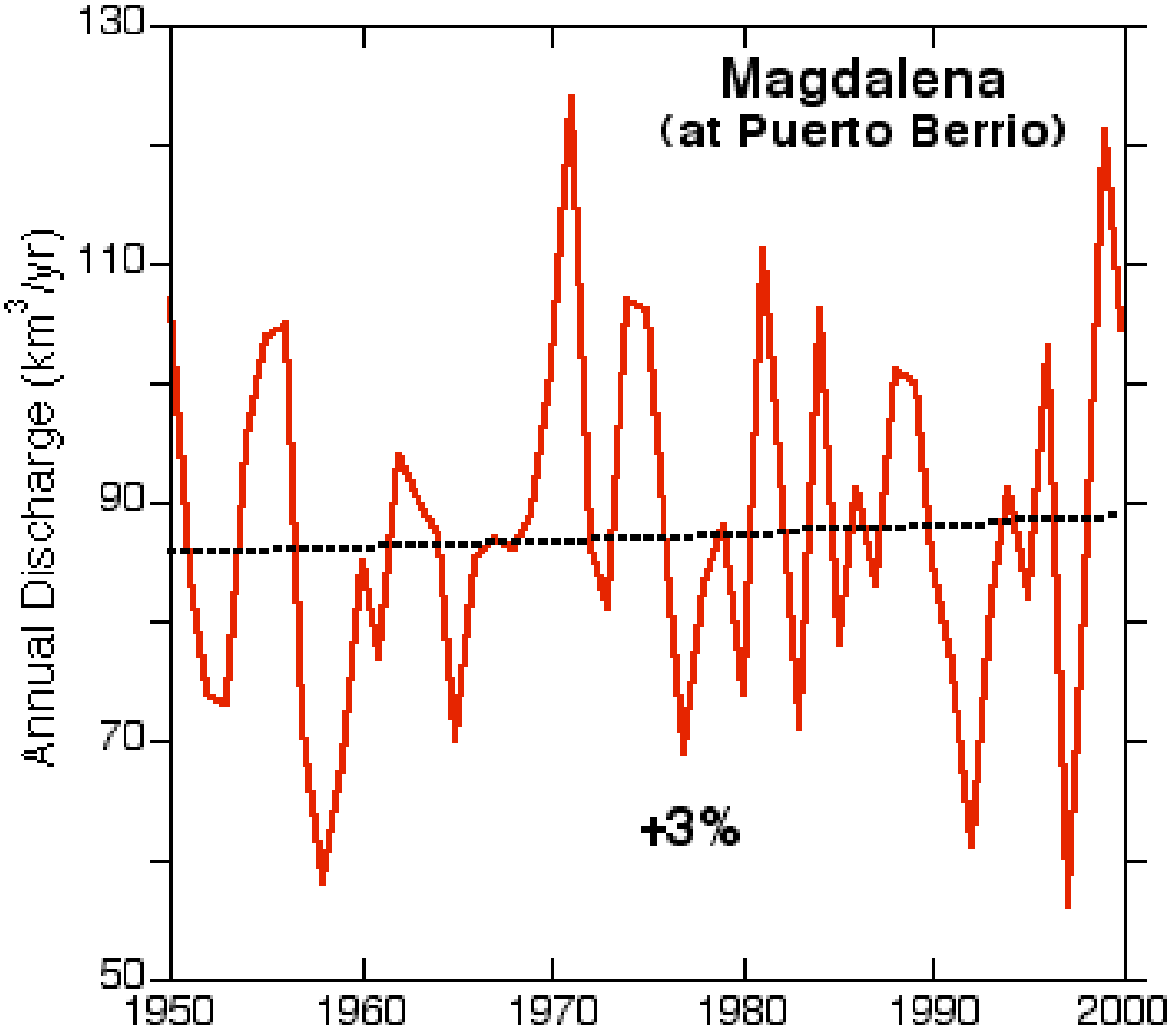
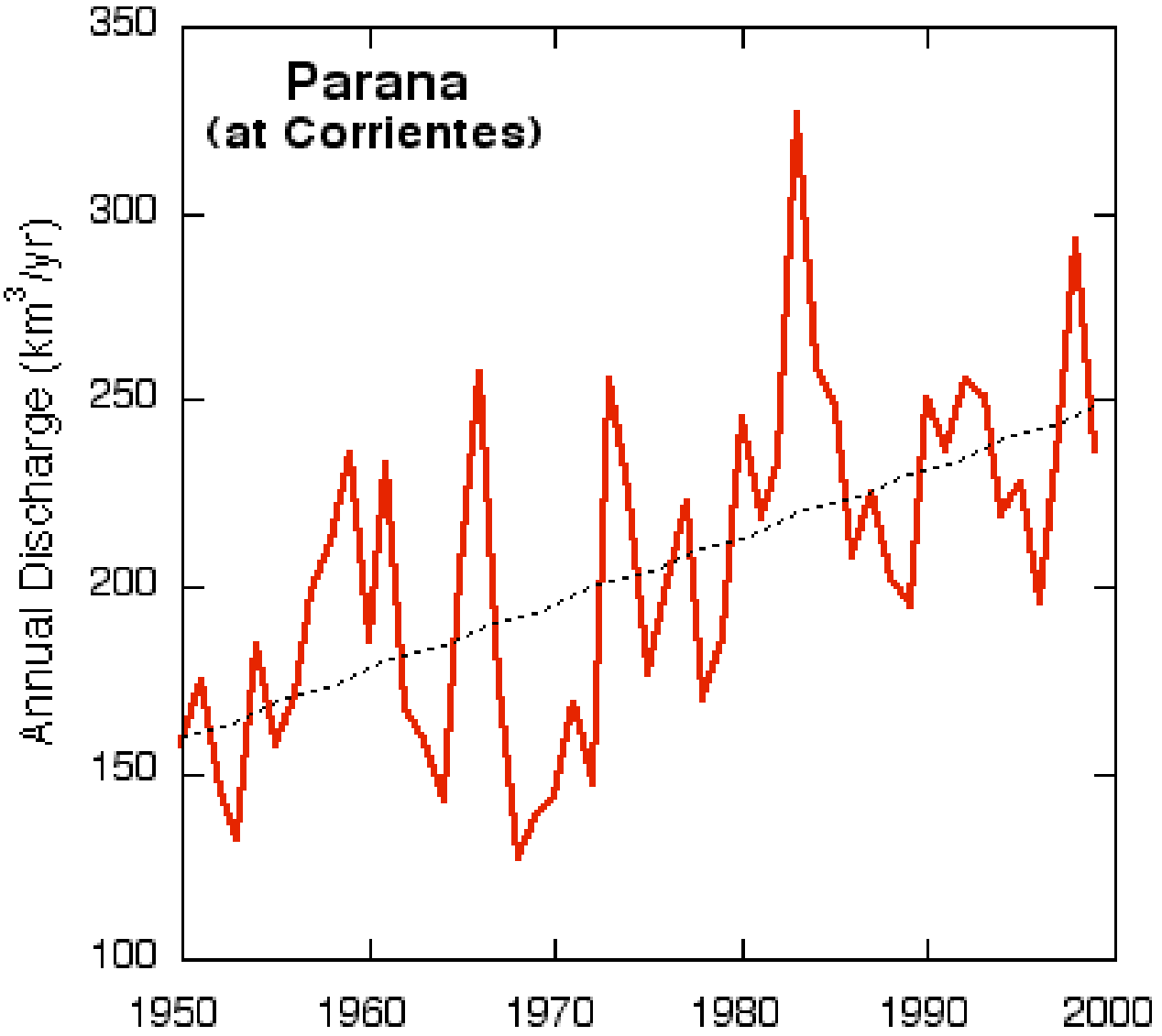
River Discharge to the Coastal Ocean: A Global Analysis

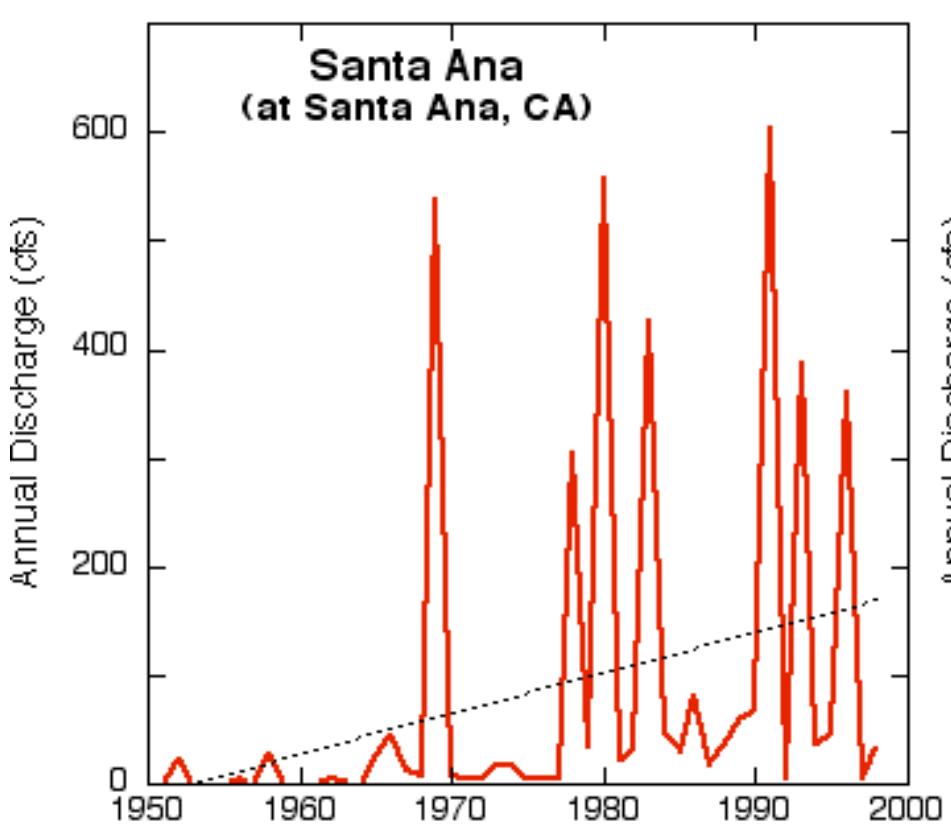
J.D. Milliman and K.L. Farnsworth
Cambridge Univ. Press

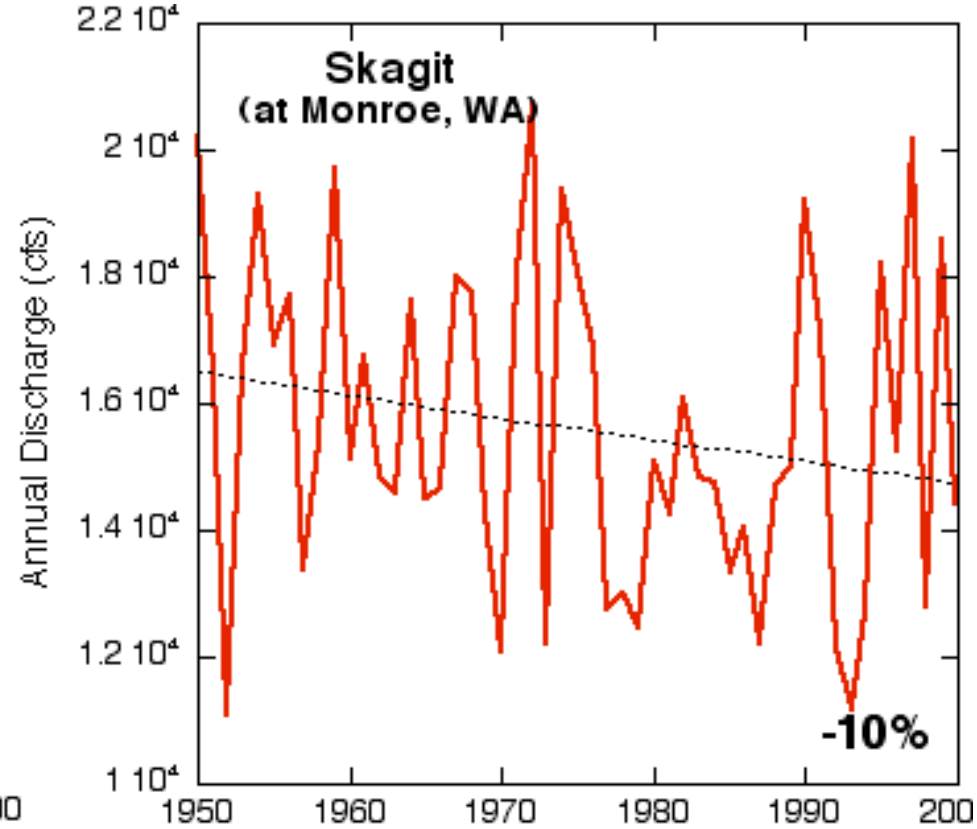
Fluvial Freshwater Discharge to the Coastal Ocean

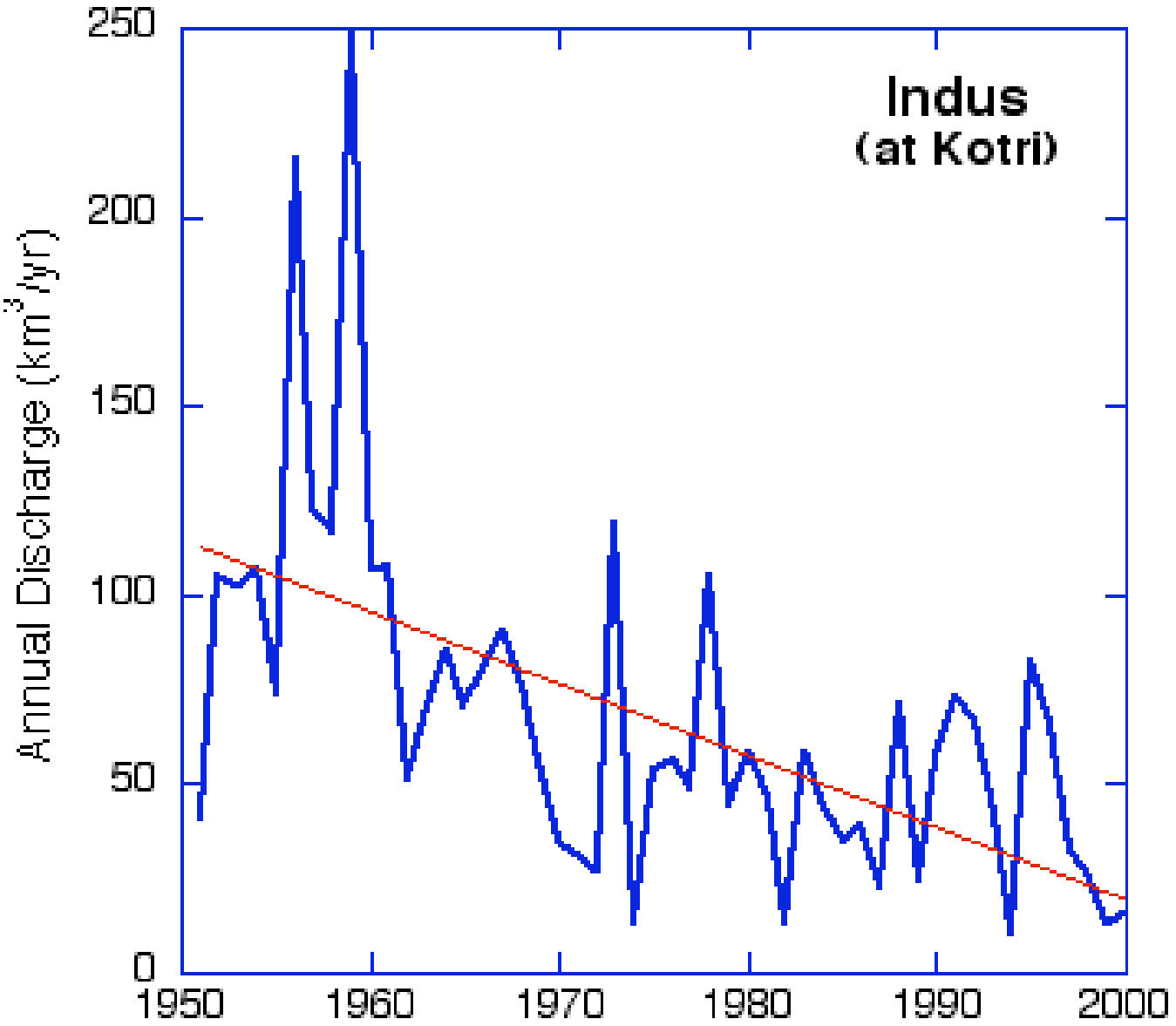


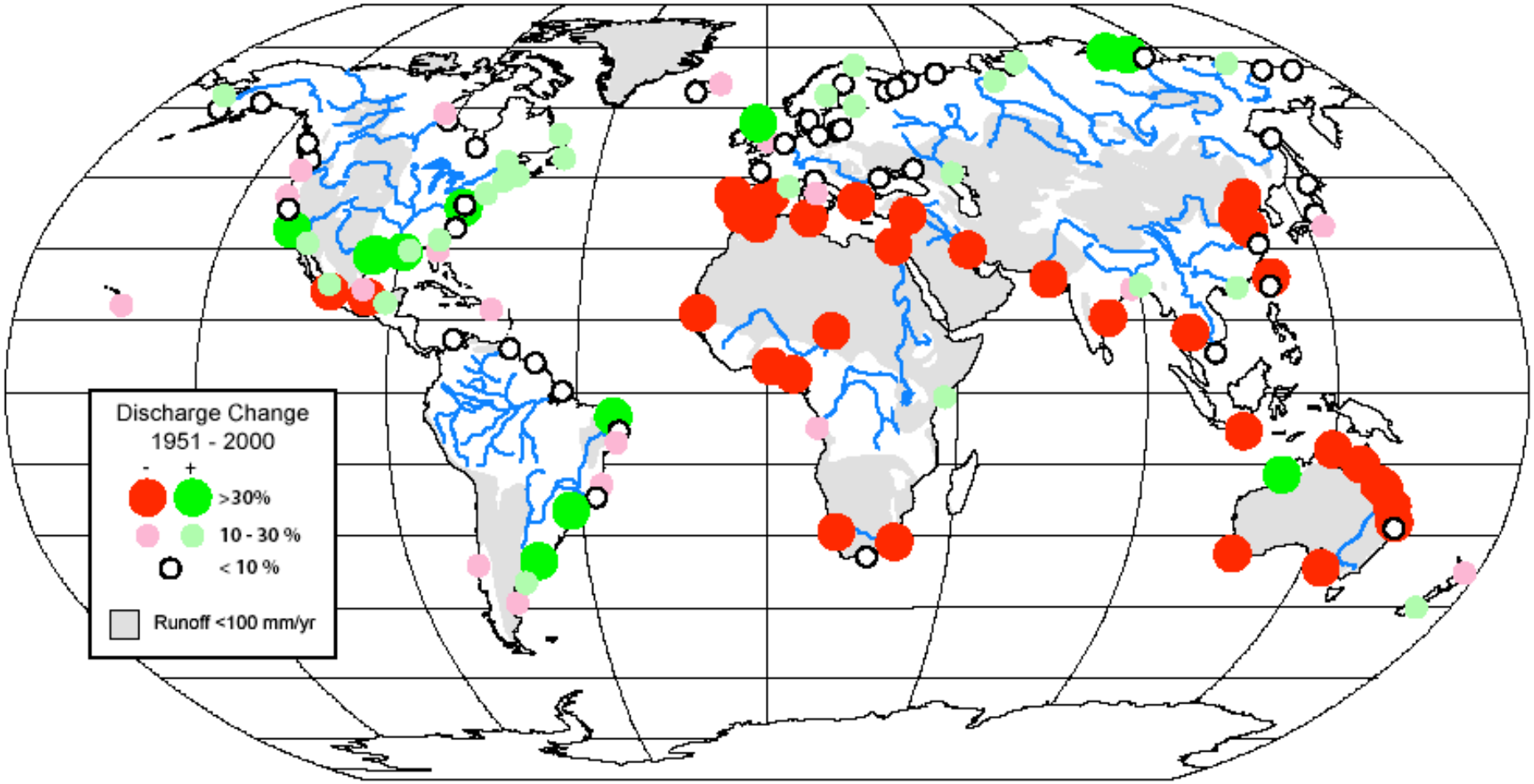

Magdalena
(at Puerto Berrio)
+3%
Annual Discharge (km3/yr)
130
110
90
70
50
1950
1960
1970
1980
1990
2000


Parana
(at Corrientes)
Annual Discharge (km3/yr)
350
300
250
200
150
100
1950
1960
1970
1980
1990
2000

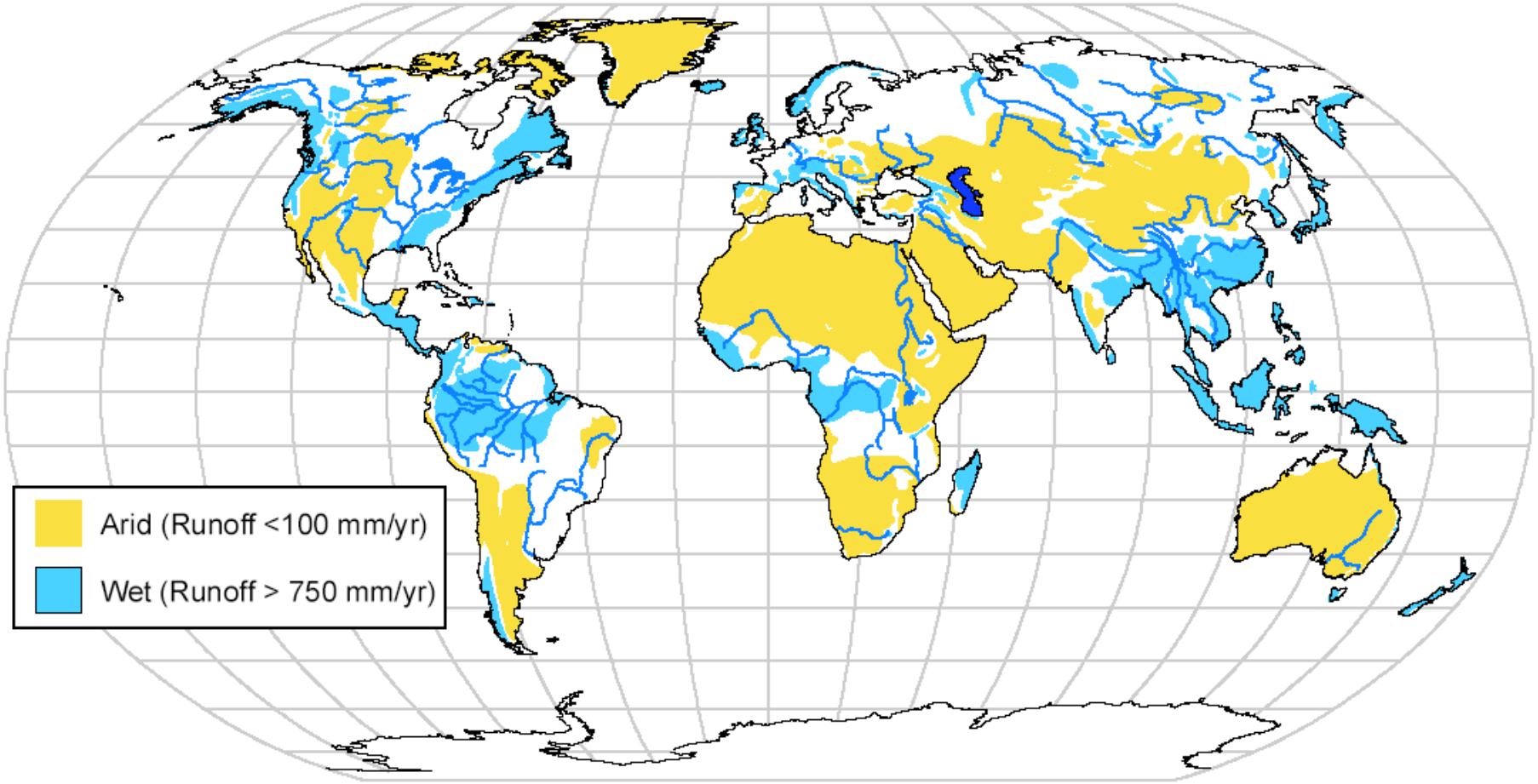

Santa Ana
(at Santa Ana, CA)
Annual Discharge (cfs)
600
400
200
0
1950
1960
1970
1980
1990
2000


Skagit
(at Monroe, WA)
Annual Discharge (cfs)
2.2 10⁴
2 10⁴
1.8 10⁴
1.6 10⁴
1.4 10⁴
1.2 10⁴
1 10⁴
-10%
1950
1960
1970
1980
1990
200


Indus
(at Kotri)
Annual Discharge (km3/yr)
250
200
150
100
50
0
1950
1960
1970
1980
1990
2000


Discharge Change
1951 - 2000
-
+
>30%
10 - 30 %
< 10 %
Runoff <100 mm/yr

Global Distribution of Arid and Wet Regions



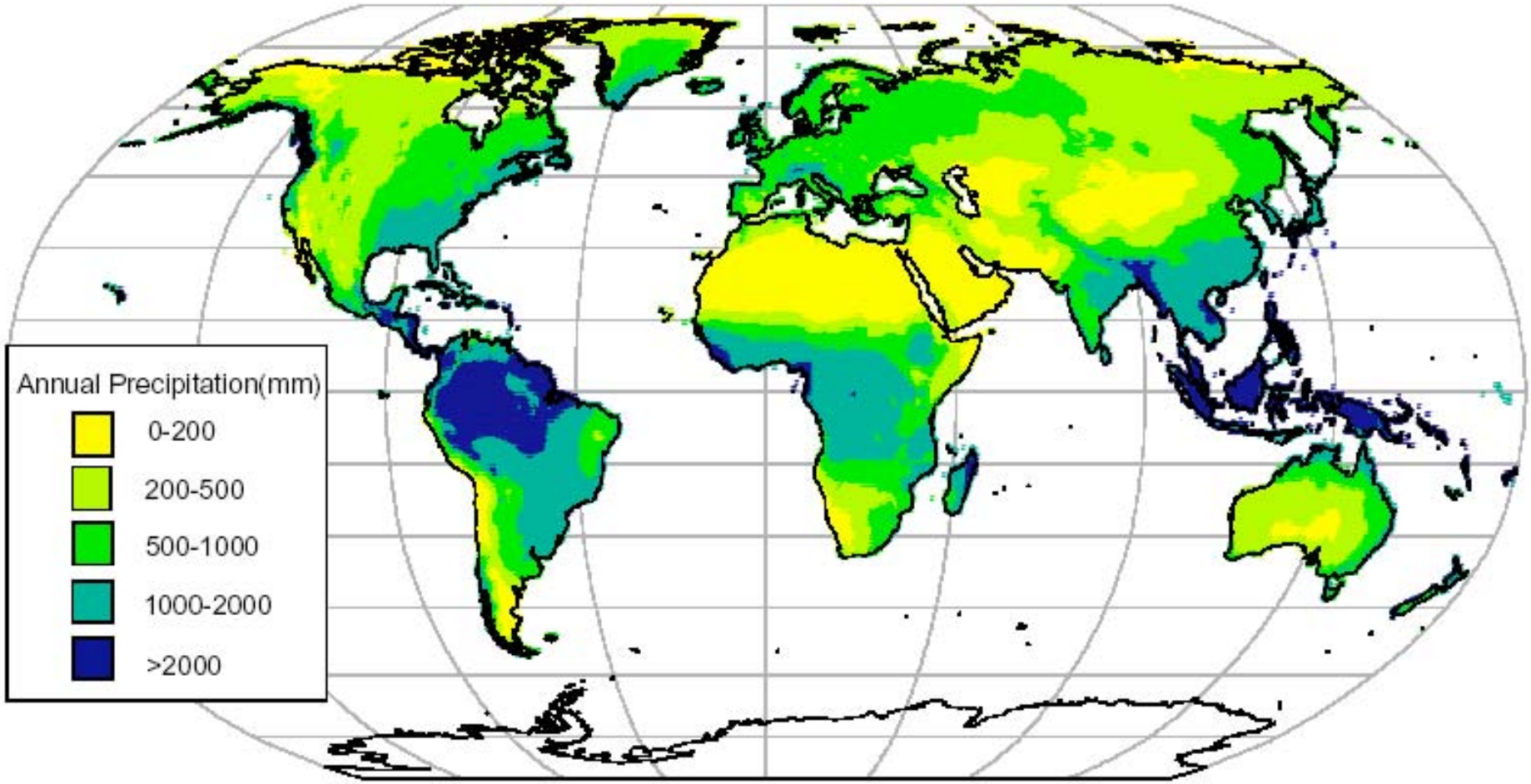
$$\Delta R = \Delta P - \Sigma(\Delta ET + \Delta S + \Delta C)$$

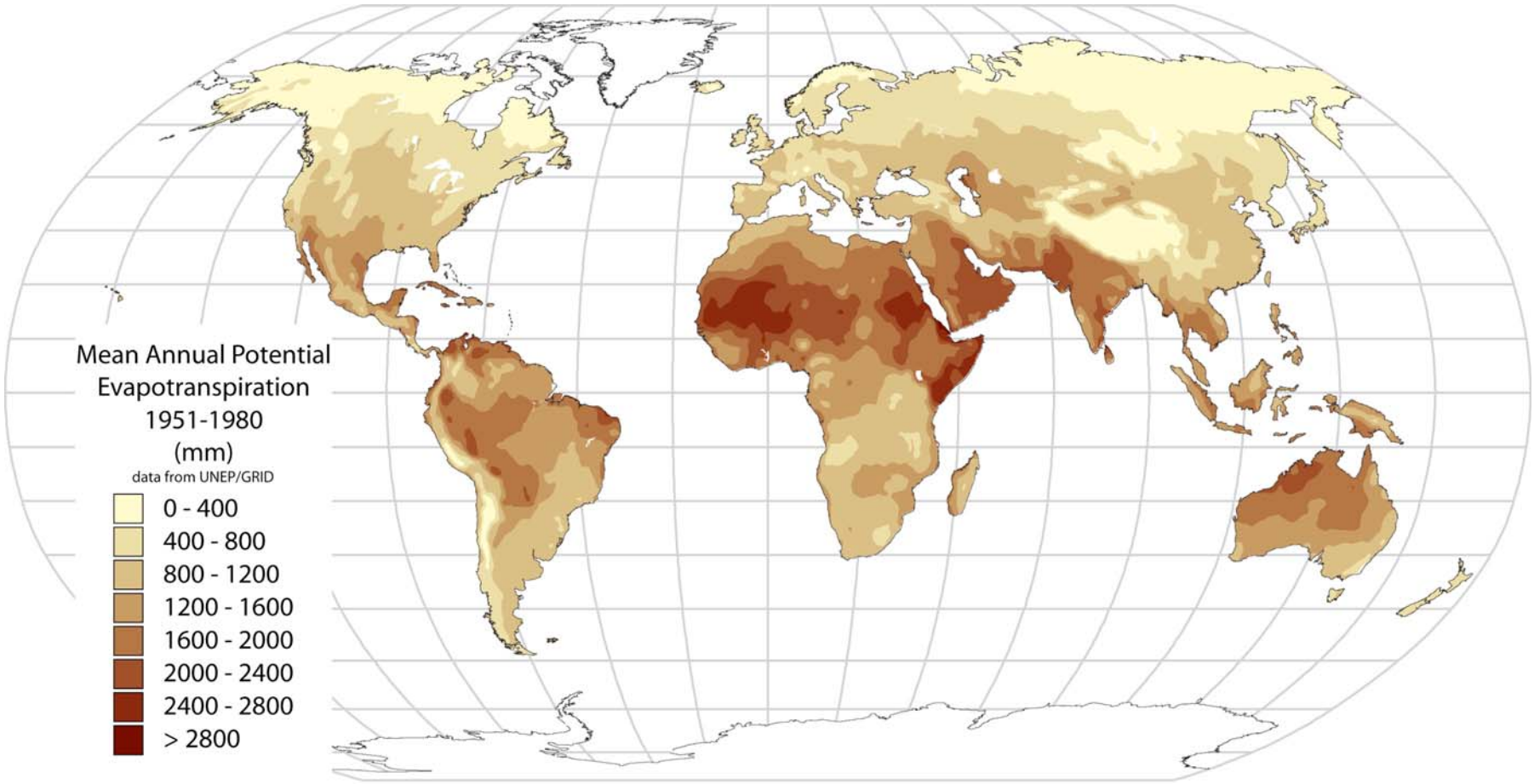
$$\Delta R = \Delta P - \Sigma(\Delta ET + \Delta S + \Delta C)$$

Long Term - Assume:

ΔS and $\Delta C = 0$

So, $\Delta R = \Delta P - \Delta ET$


Annual Precipitation(mm)
0-200
200-500
500-1000
1000-2000
>2000


Mean Annual Potential
Evapotranspiration
1951-1980
(mm)
data from UNEP/GRID
0 - 400
400 - 800
800 - 1200
1200 - 1600
1600 - 2000
2000 - 2400
2400 - 2800
> 2800

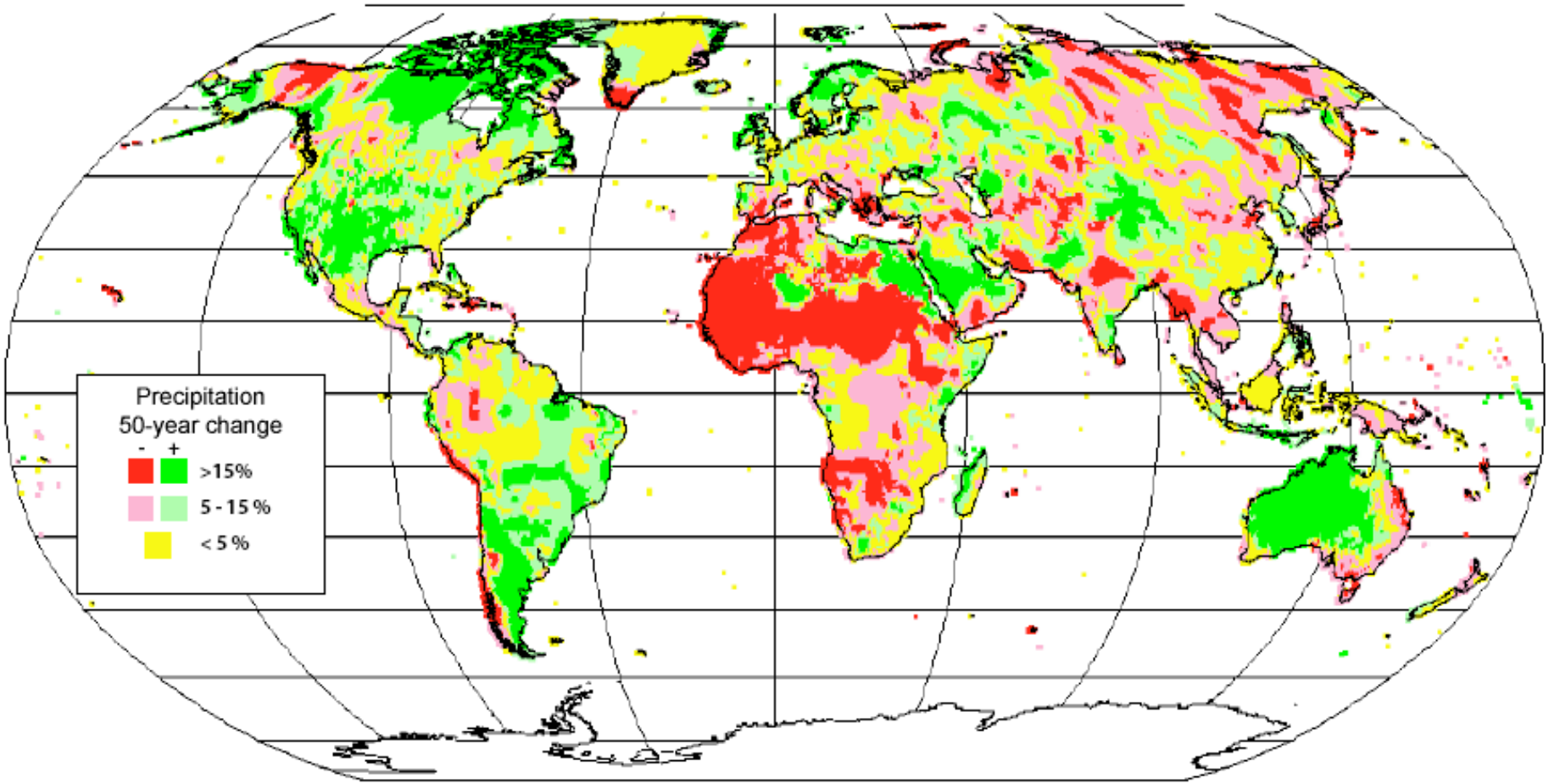
$$\Delta R = \Delta P - \Sigma(\Delta ET + \Delta S + \Delta C)$$

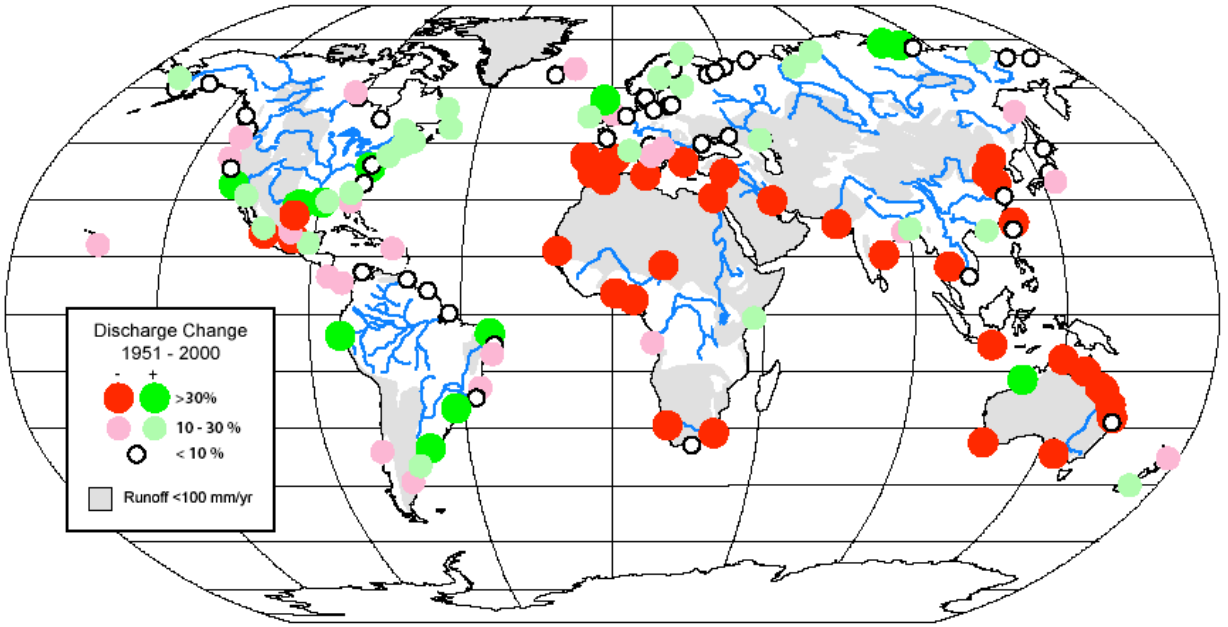
Long Term: ΔS and $\Delta C = 0$

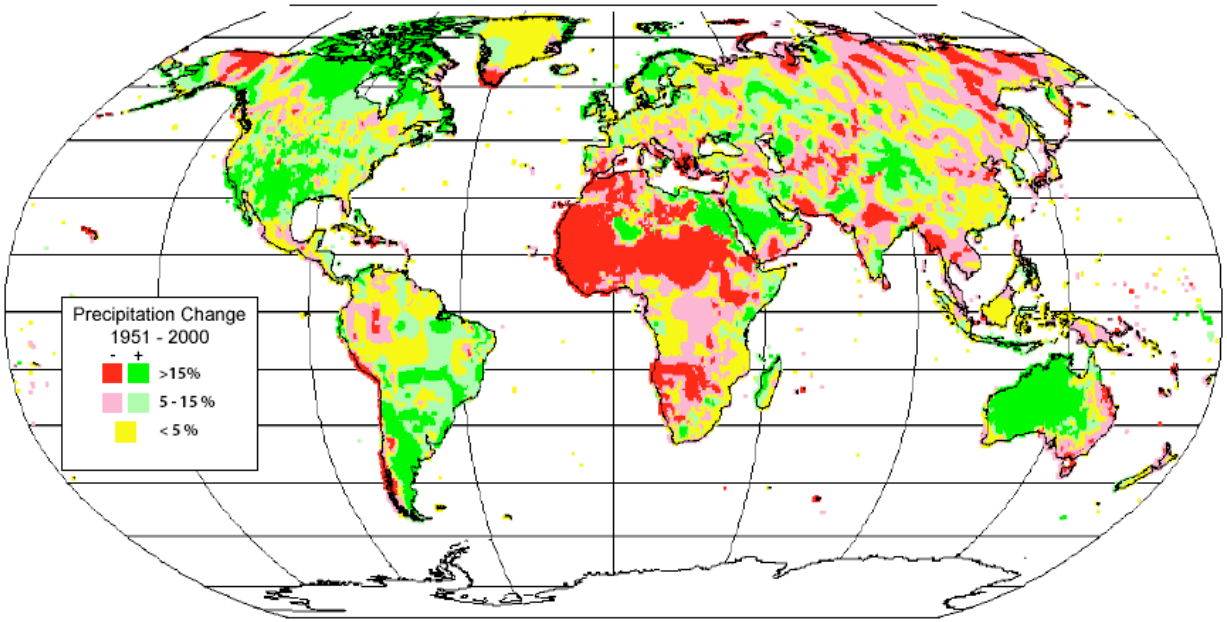
So, $\Delta R = \Delta P - \Delta ET$

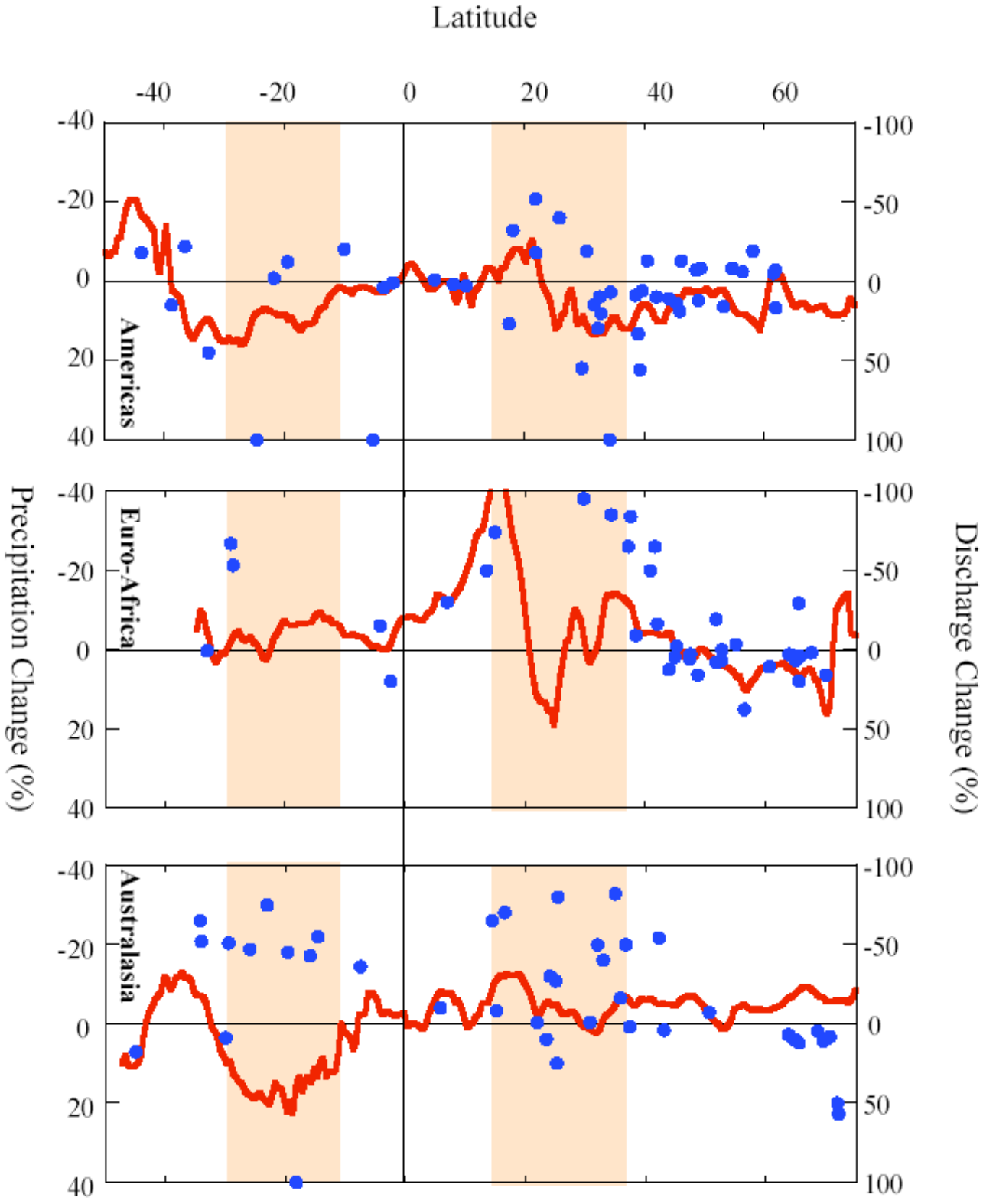
If $\Delta ET \sim 0$,

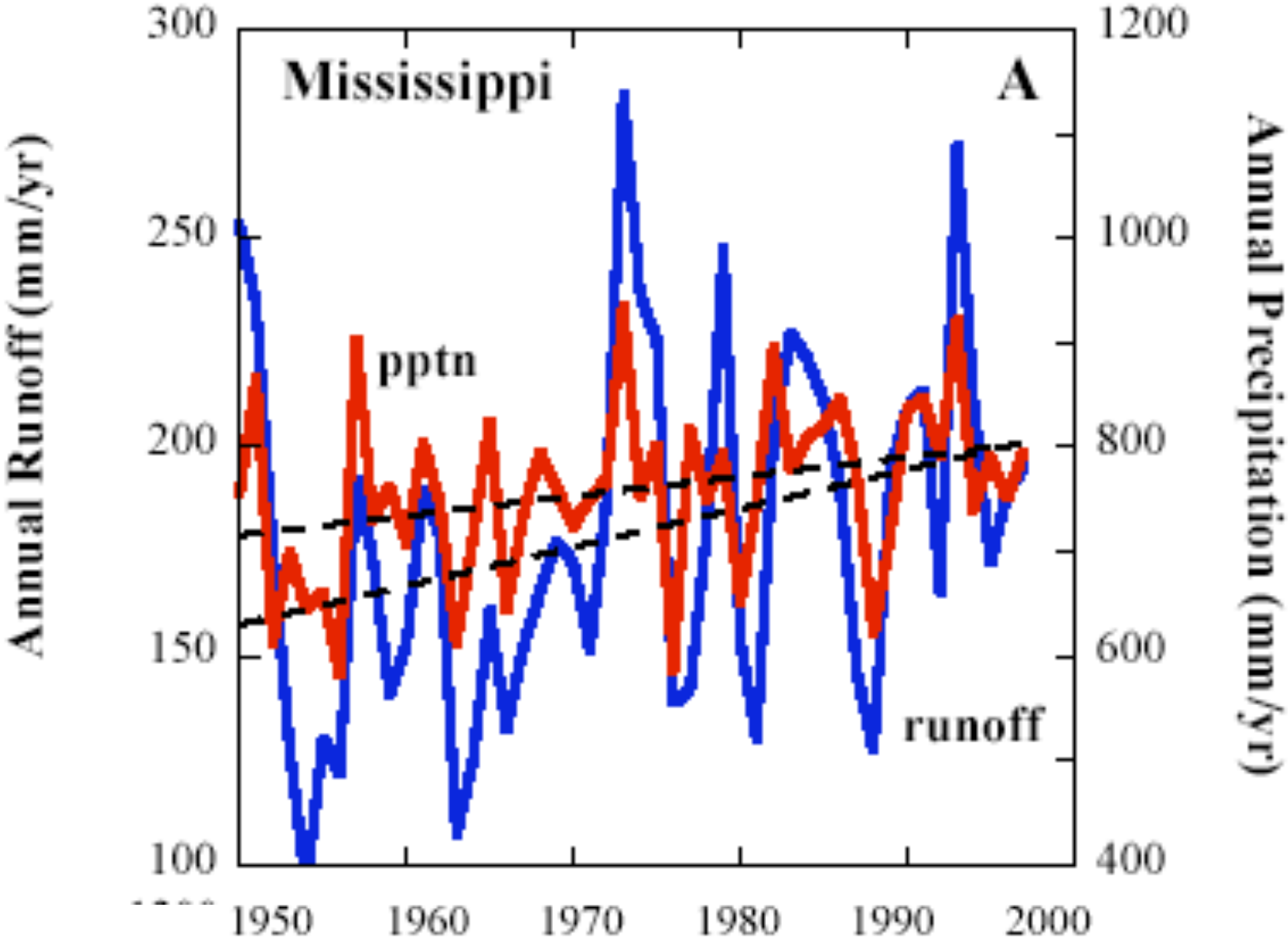
Then $\Delta R = f\Delta P$

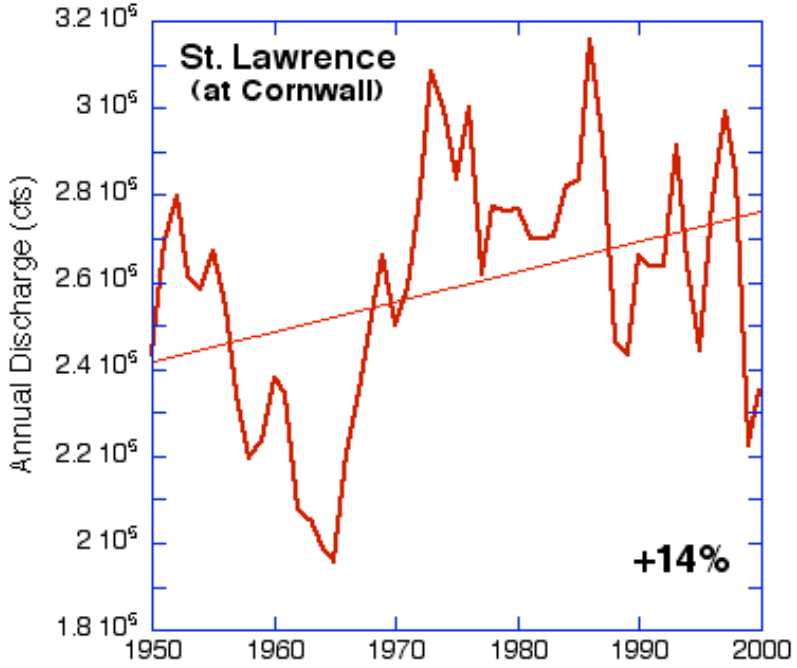

Precipitation
50-year change
- +
>15%
5 - 15 %
< 5 %

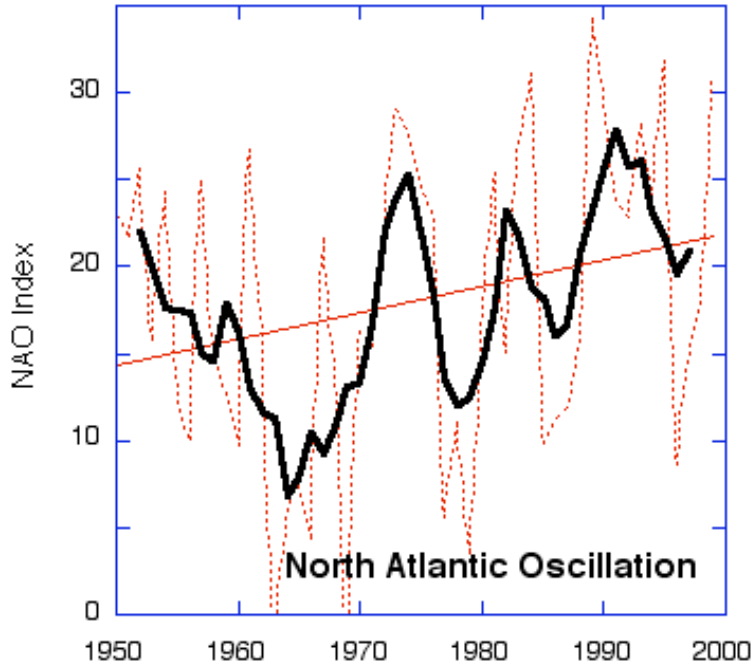

Discharge Change
1951 - 2000
- +
>30%
10 - 30 %
< 10 %
Runoff <100 mm/yr

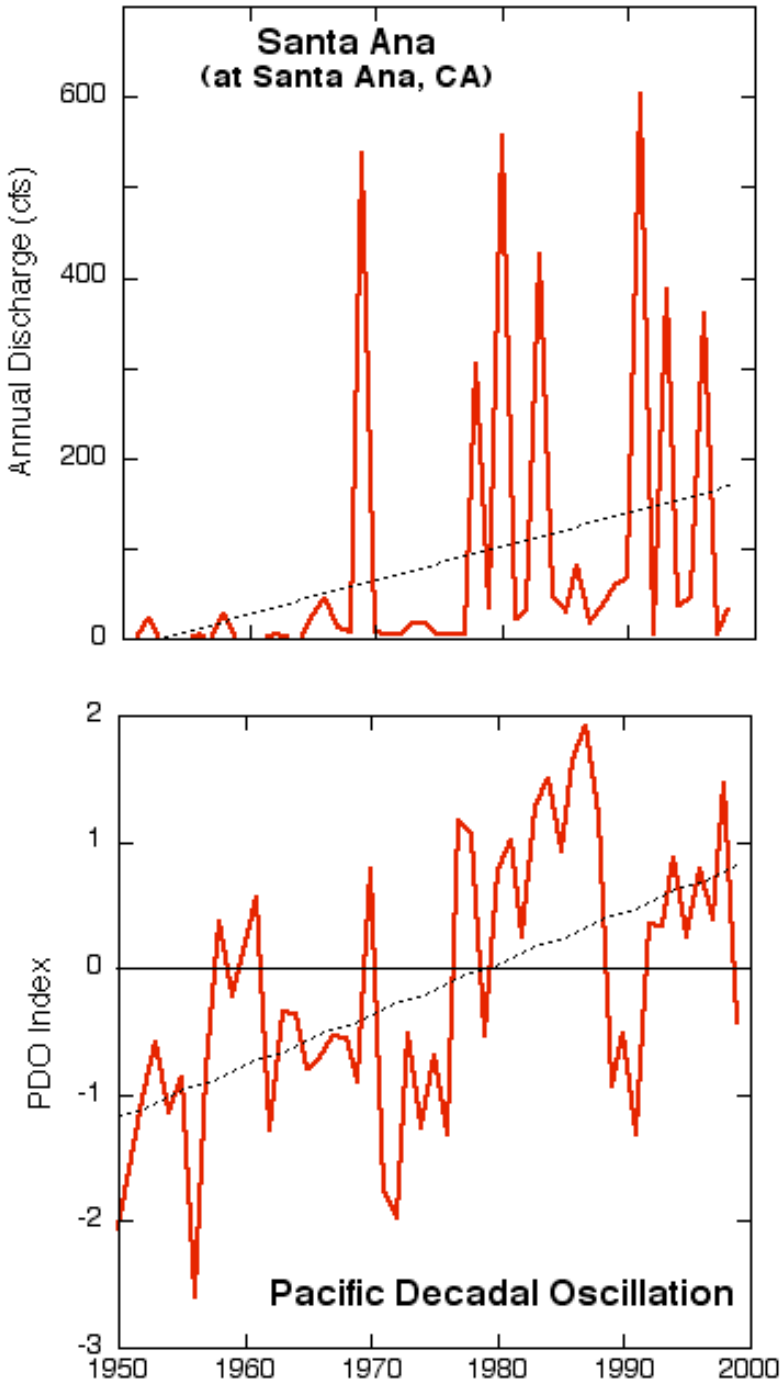

Precipitation Change
1951 - 2000
- +
>15%
5 - 15 %
< 5 %

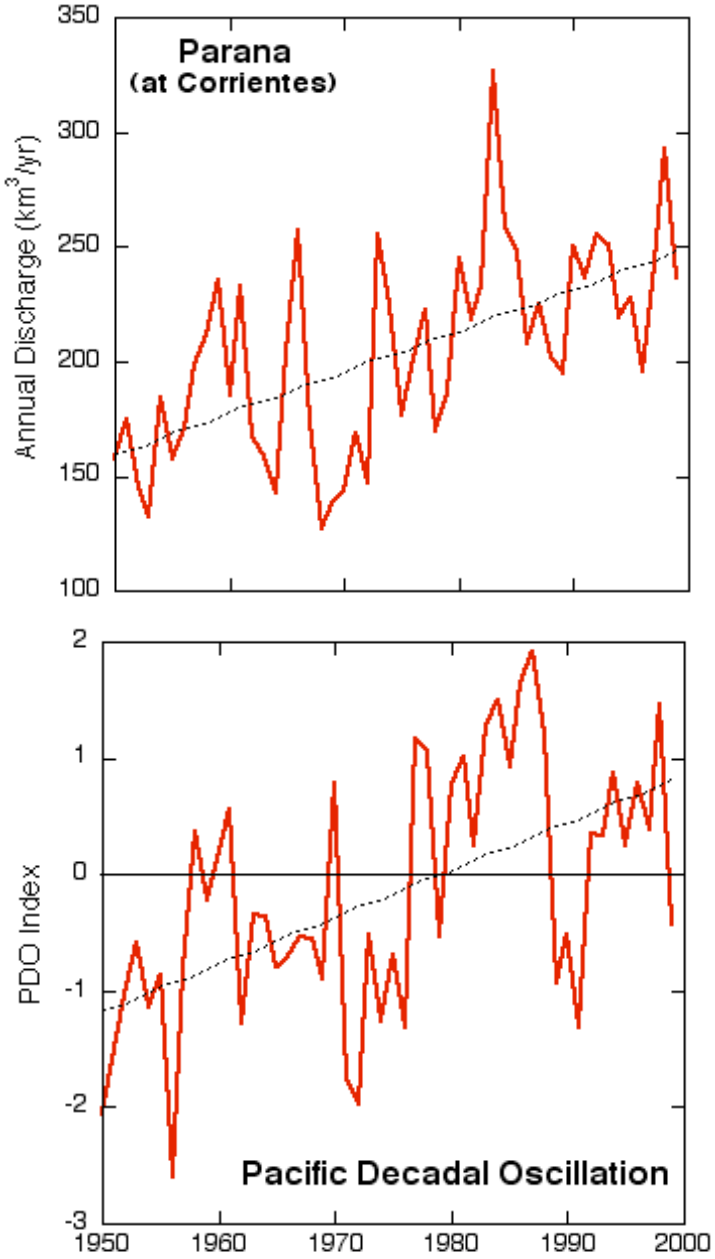

Latitude
-40
-20
0
20
40
60
Precipitation Change (%)
Discharge Change (%)
Americas
Euro-Africa
Australasia
-40
-20
0
20
40
-100
-50
0
50
100

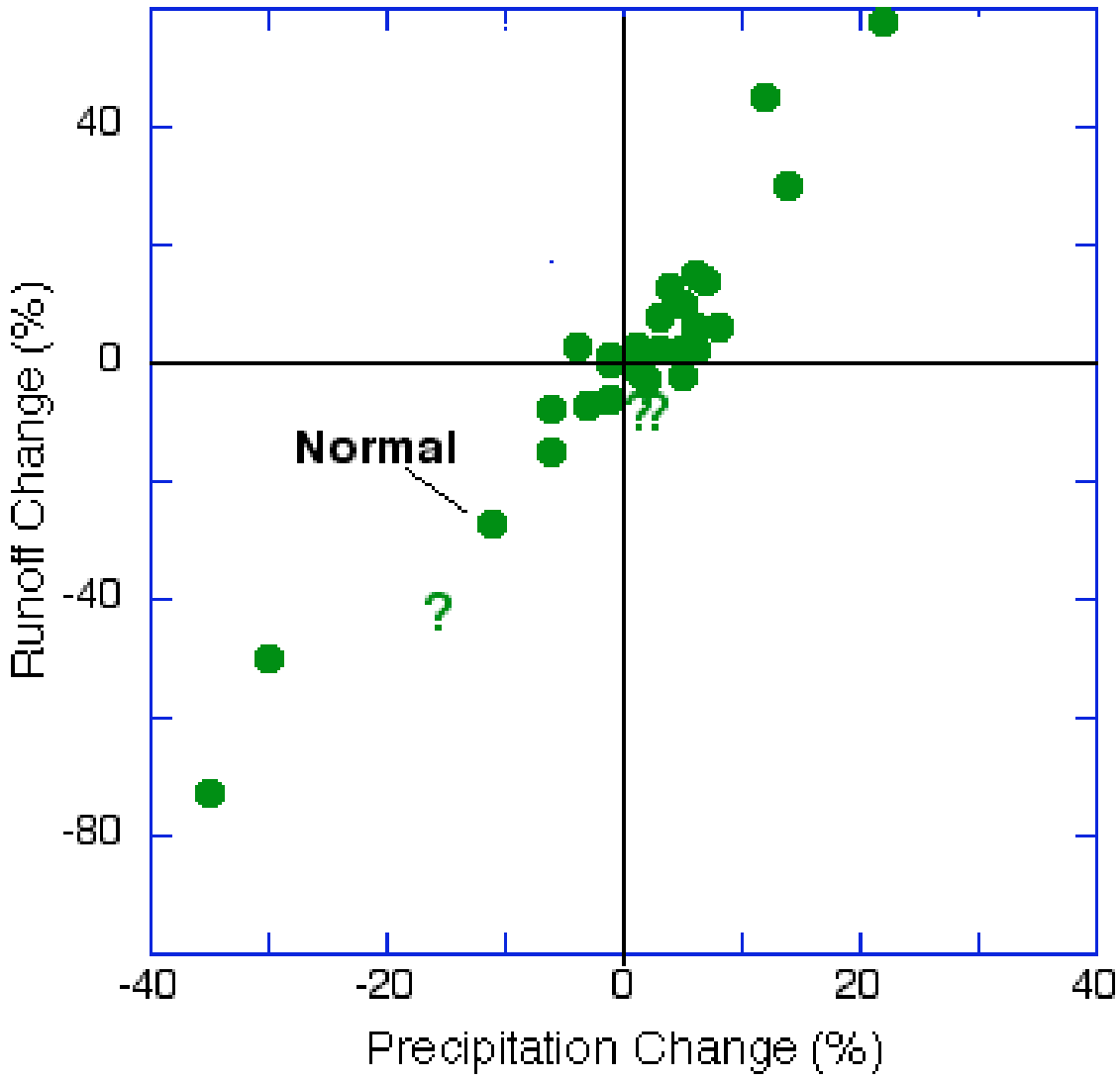

Mississippi
A
pptn
runoff
Annual Runoff (mm/yr)
Annual Precipitation (mm/yr)
300
250
200
150
100
1200
1000
800
600
400
1950
1960
1970
1980
1990
2000

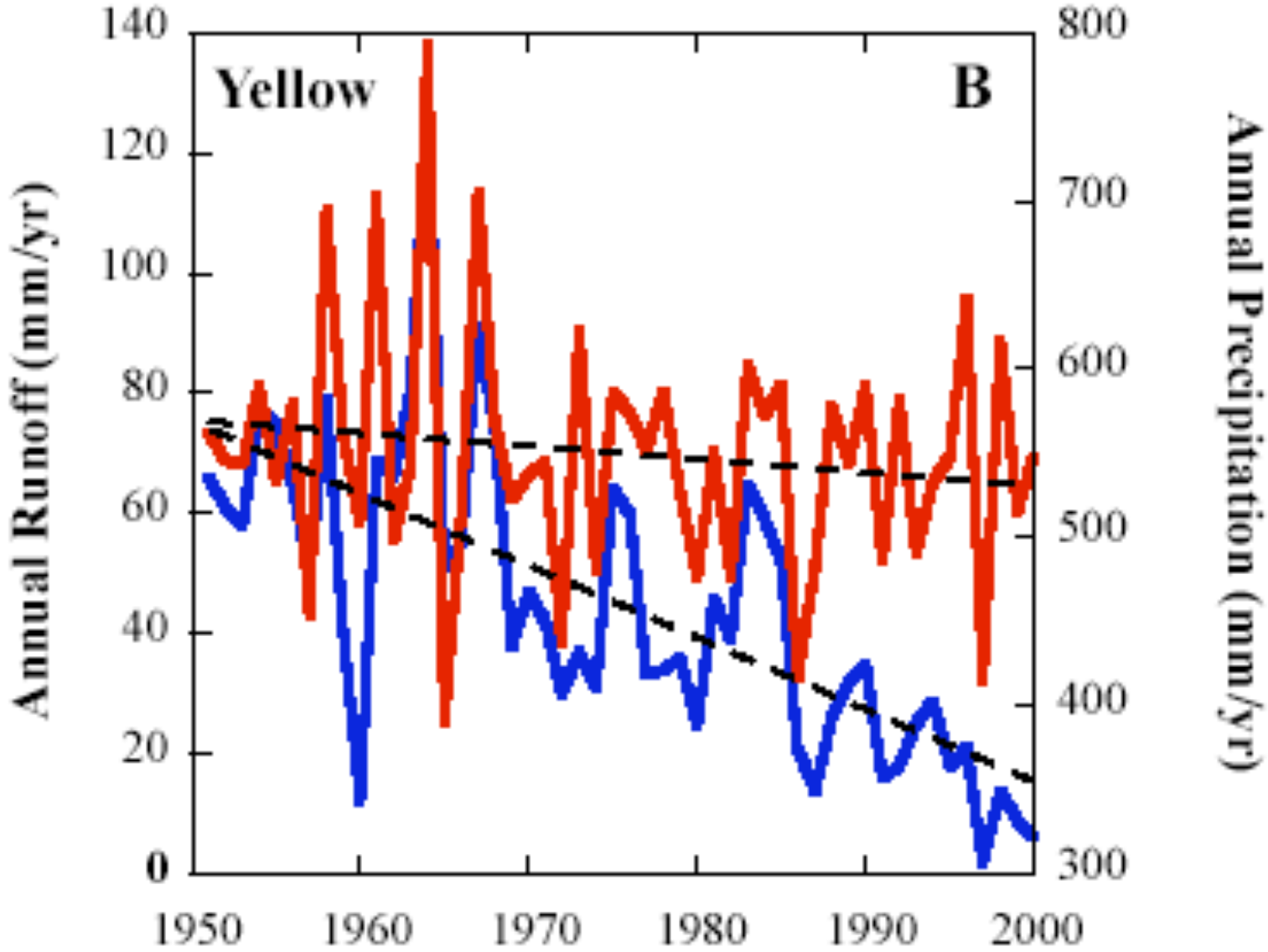

St. Lawrence
(at Cornwall)
Annual Discharge (cfs)
3.2 10⁵
3 10⁵
2.8 10⁵
2.6 10⁵
2.4 10⁵
2.2 10⁵
2 10⁵
1.8 10⁵
1950
1960
1970
1980
1990
2000
+14%

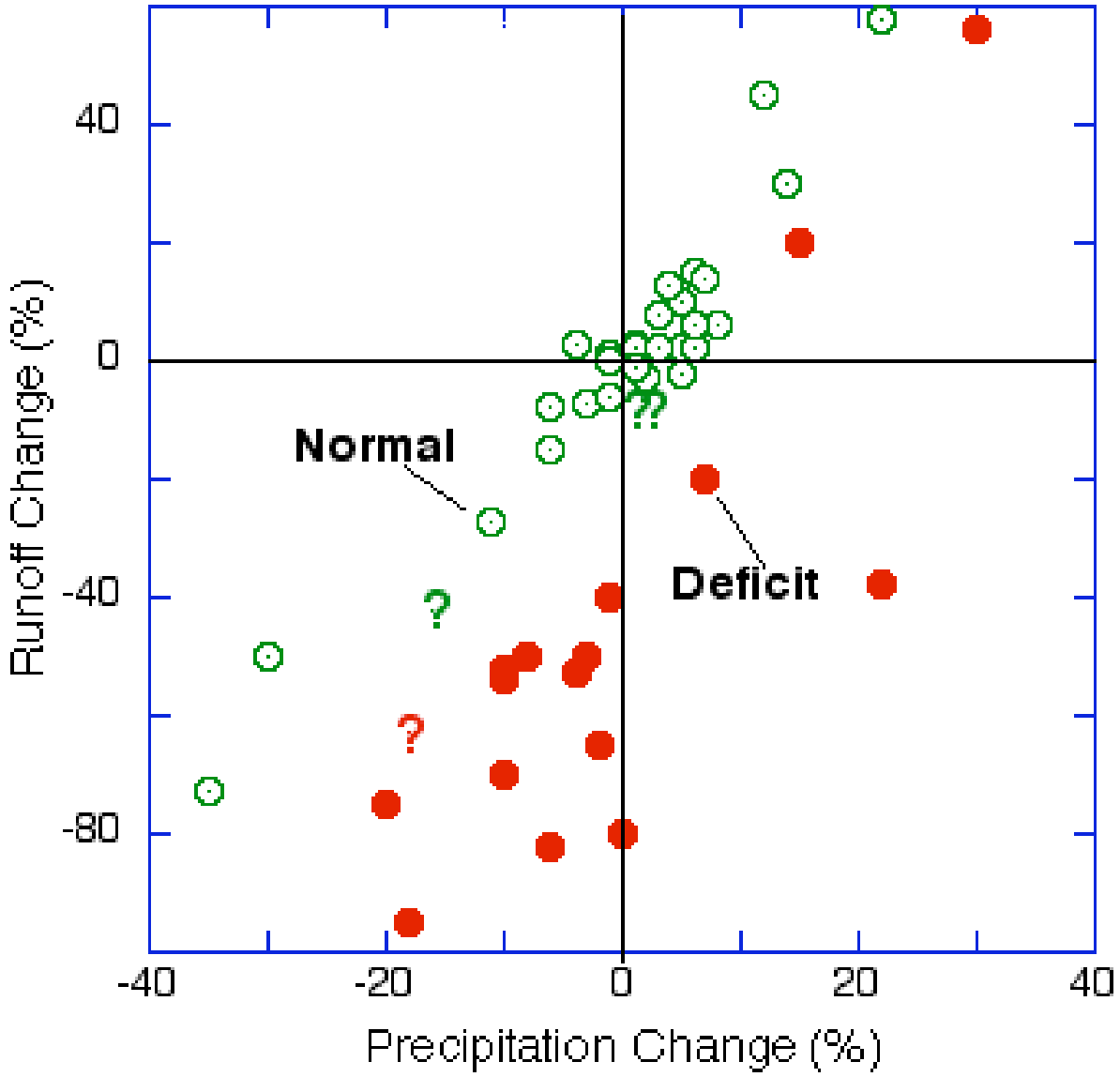

NAO Index
30
20
10
0
1950
1960
1970
1980
1990
2000
North Atlantic Oscillation


Santa Ana
(at Santa Ana, CA)
Annual Discharge (cfs)
600
400
200
0
PDO Index
2
1
0
-1
-2
-3
Pacific Decadal Oscillation
1950
1960
1970
1980
1990
2000


Parana
(at Corrientes)
Annual Discharge (km3/yr)
350
300
250
200
150
100
PDO Index
2
1
0
-1
-2
-3
Pacific Decadal Oscillation
1950
1960
1970
1980
1990
2000


40
0
-40
-80
Runoff Change (%)
Normal
?
??
-40
-20
0
20
40
Precipitation Change (%)


Yellow
B
Annual Runoff (mm/yr)
Annual Precipitation (mm/yr)
140
120
100
80
60
40
20
0
800
700
600
500
400
300
1950
1960
1970
1980
1990
2000


40
0
-40
-80
Runoff Change (%)
-40
-20
0
20
40
Precipitation Change (%)
Normal
Deficit
?
?
??

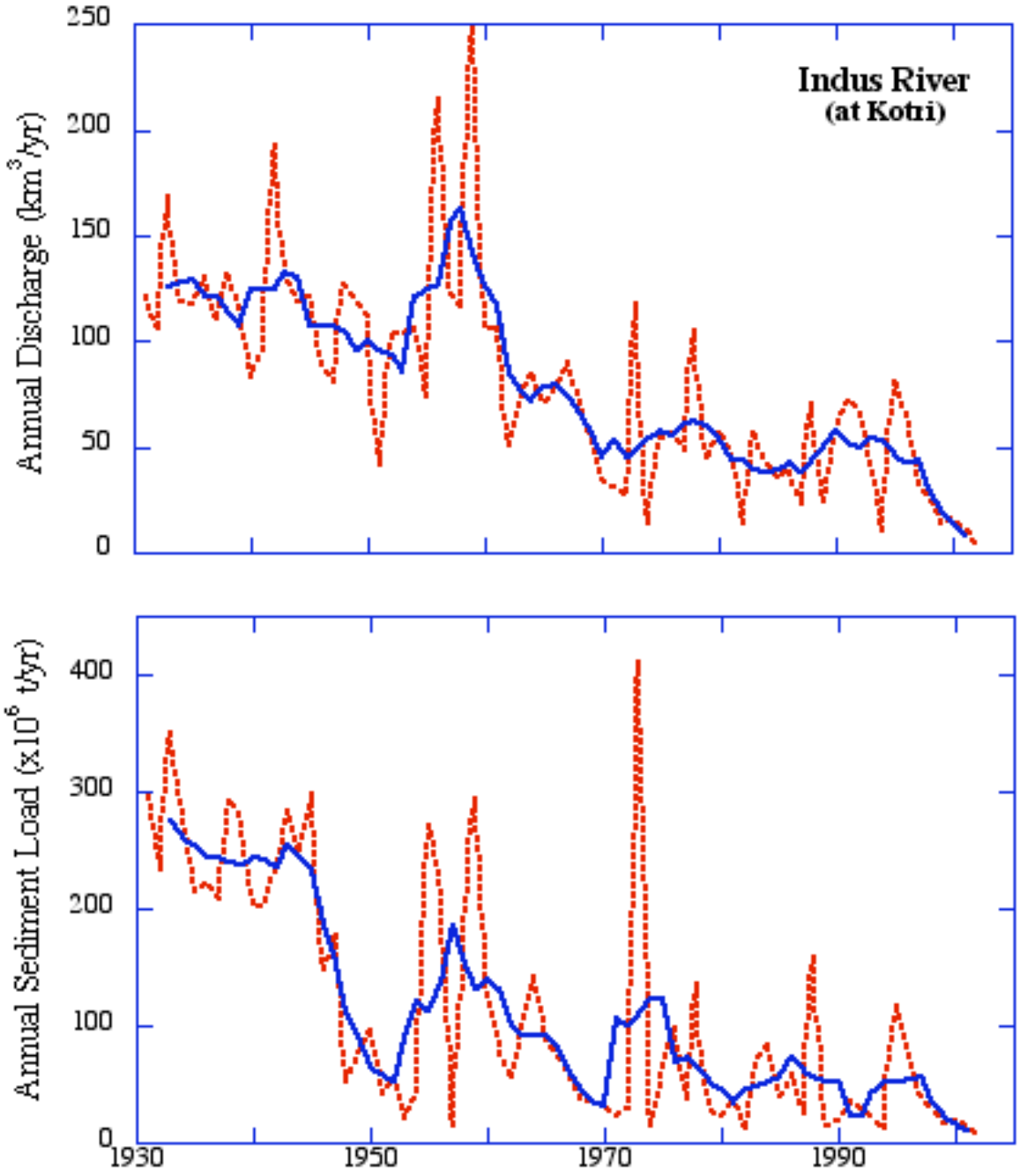

Indus River
(at Kotri)
Annual Discharge (km3/yr)
250
200
150
100
50
0
Annual Sediment Load (x10^6 t/yr)
400
300
200
100
0
1930
1950
1970
1990


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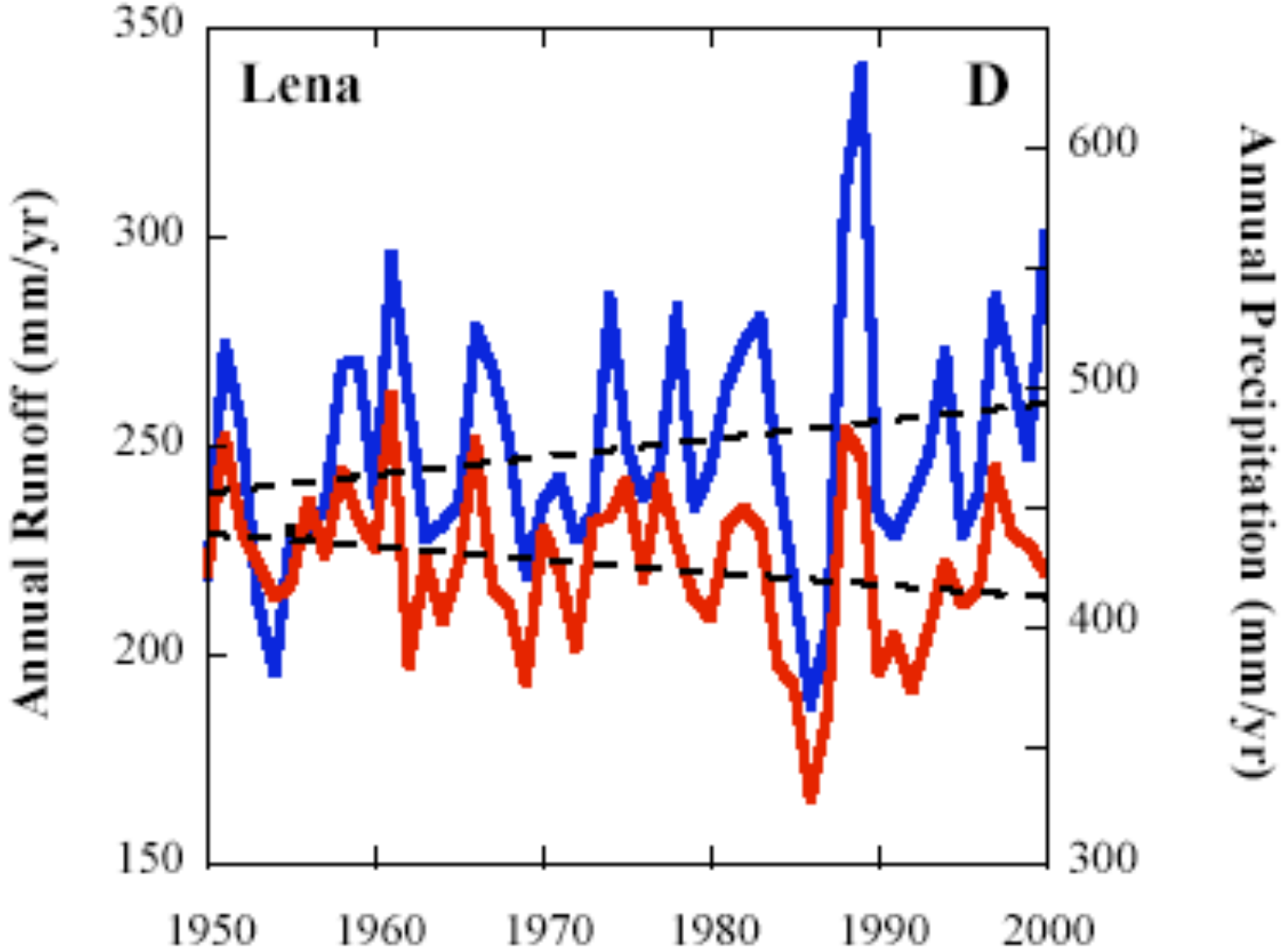
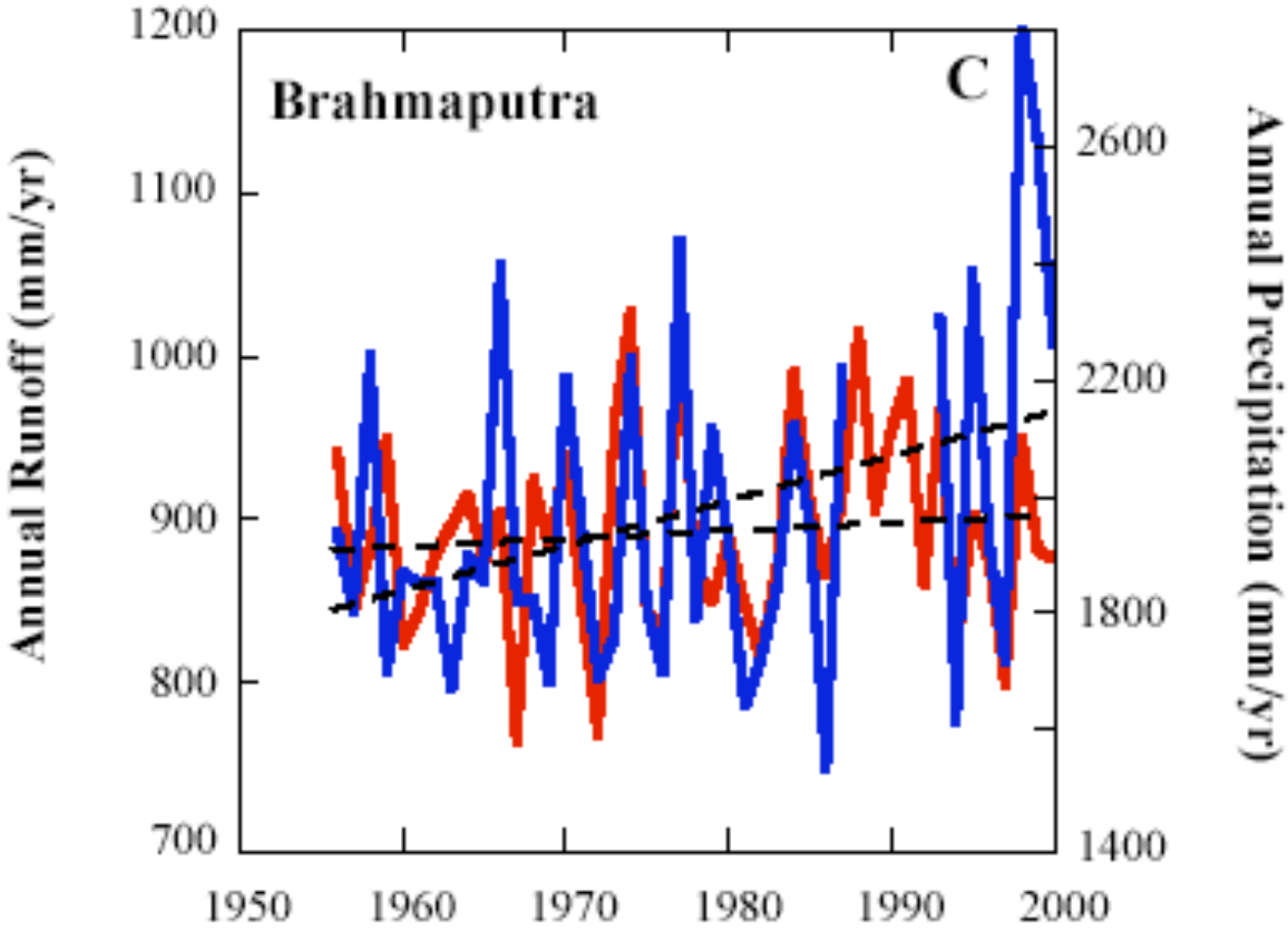
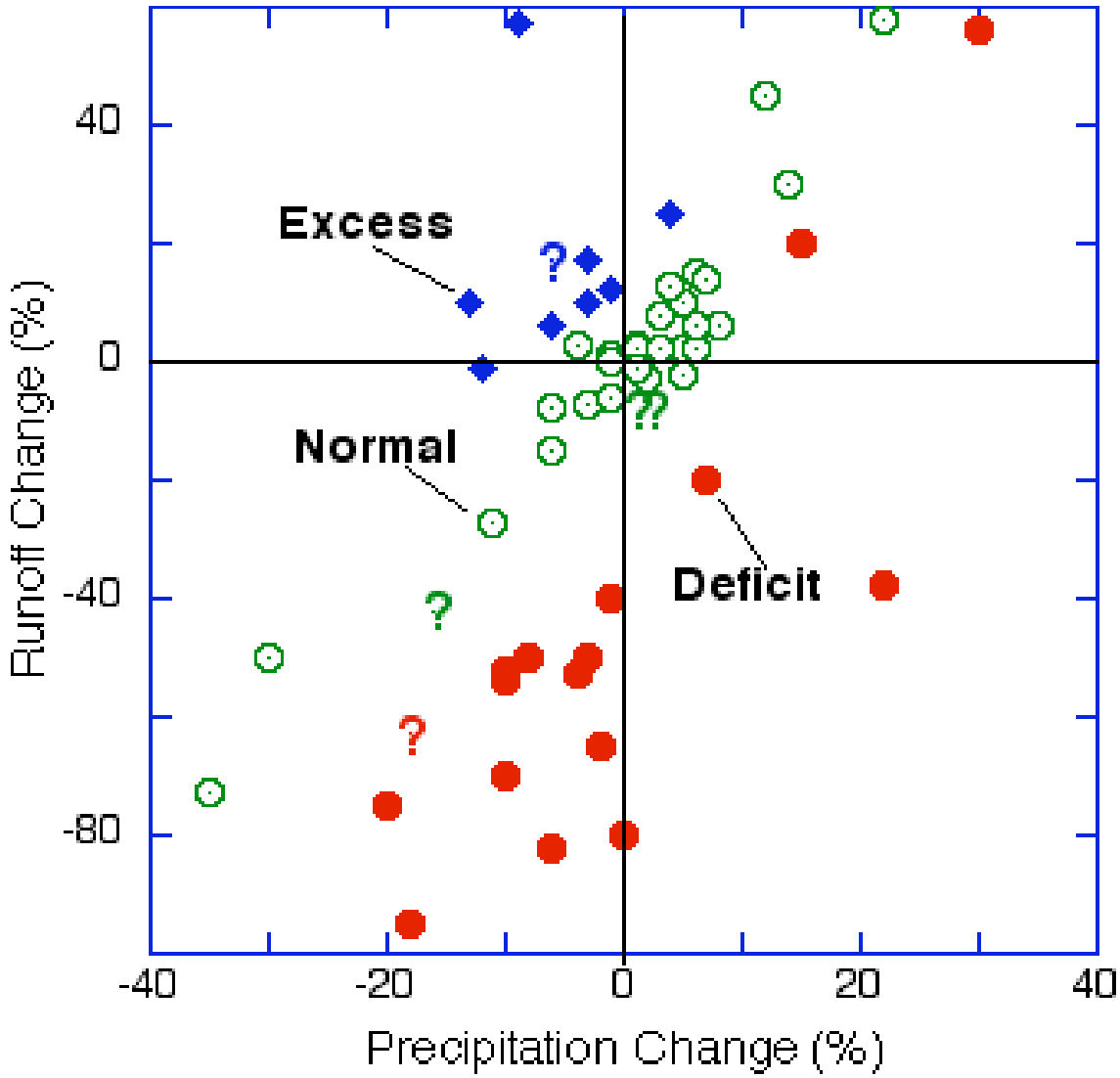
Image © 2007 DigitalGlobe
Pointer 24°45'09.22" N 67°57'31.90" E elev 12 m
Streaming 100%


Lena
D
Annual Runoff (mm/yr)
Annual Precipitation (mm/yr)
350
300
250
200
150
600
500
400
300
1950
1960
1970
1980
1990
2000


Brahmaputra
C
Annual Runoff (mm/yr)
Annual Precipitation (mm/yr)
1200
1100
1000
900
800
700
2600
2200
1800
1400
1950
1960
1970
1980
1990
2000


Excess
Normal
Deficit
?
?
?
?
40
0
-40
-80
-40
-20
0
20
40
Runoff Change (%)
Precipitation Change (%)

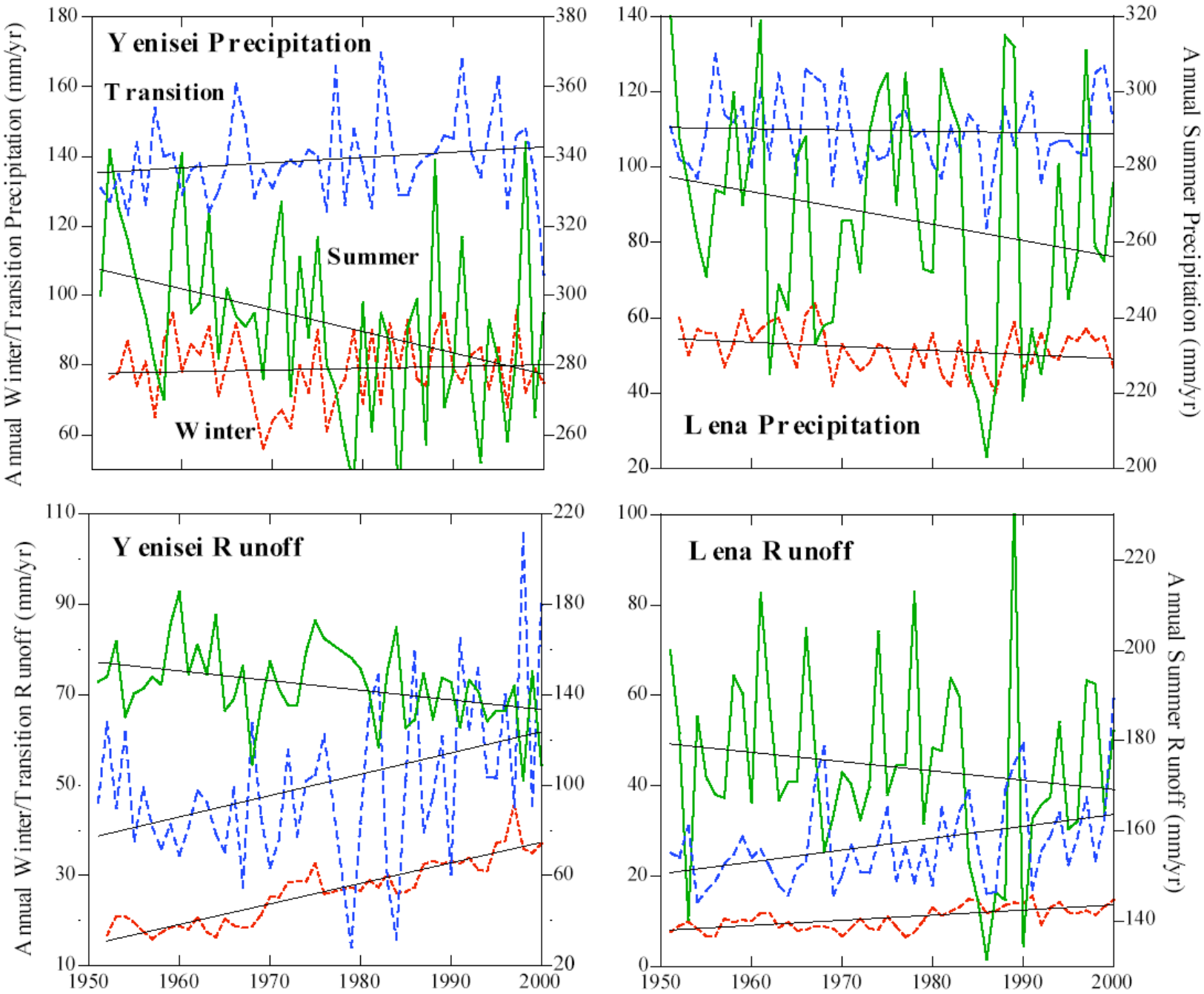
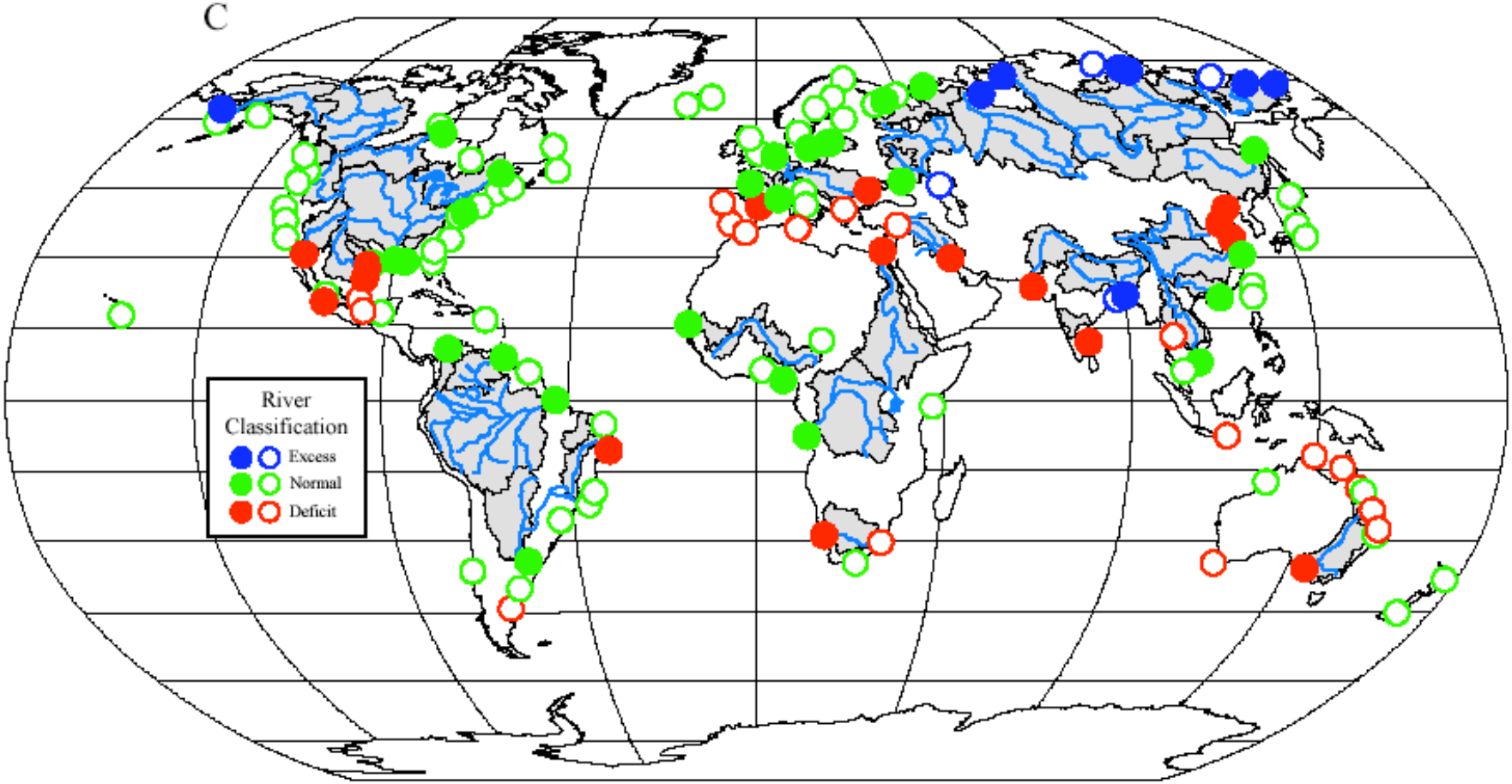
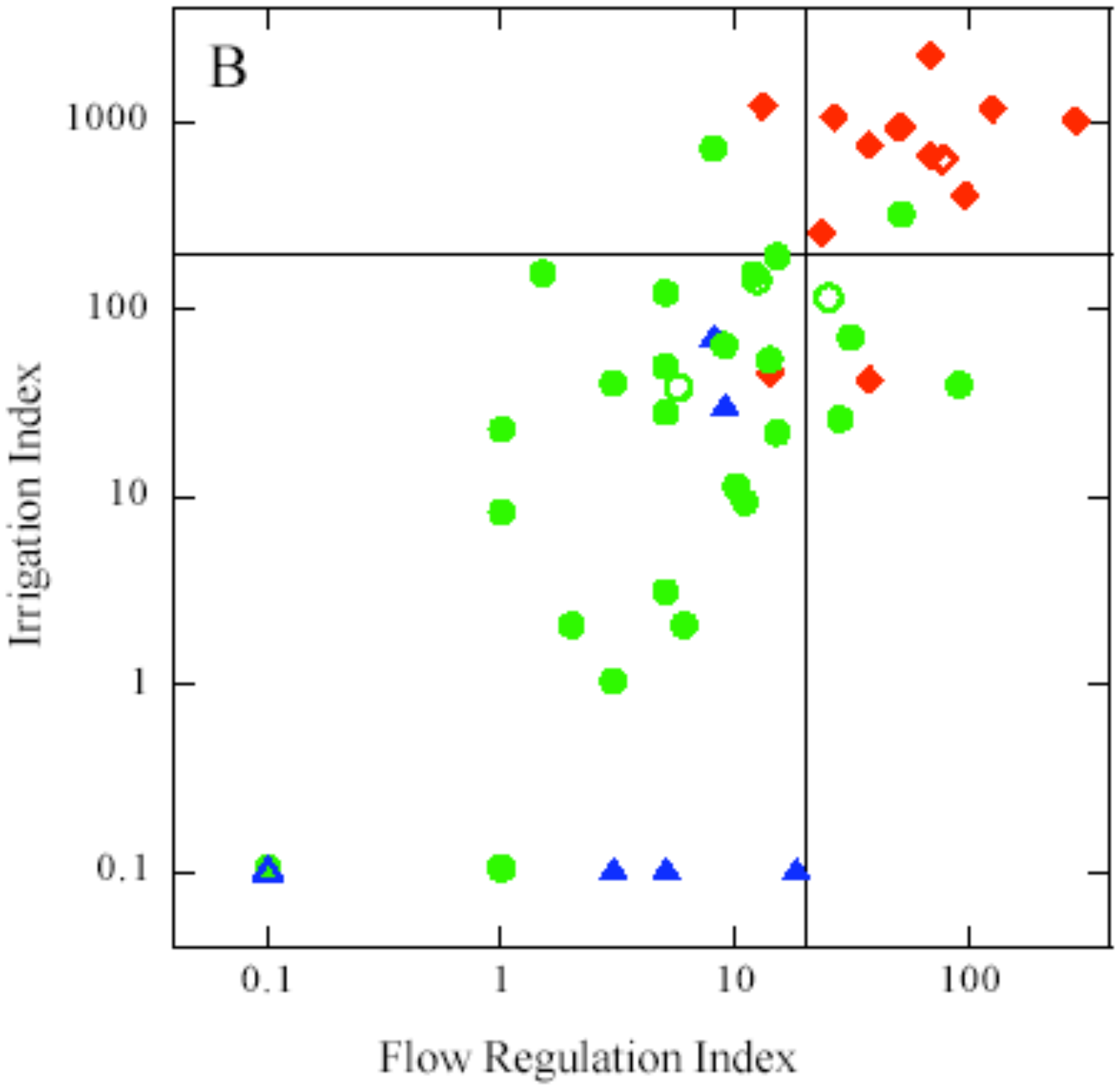
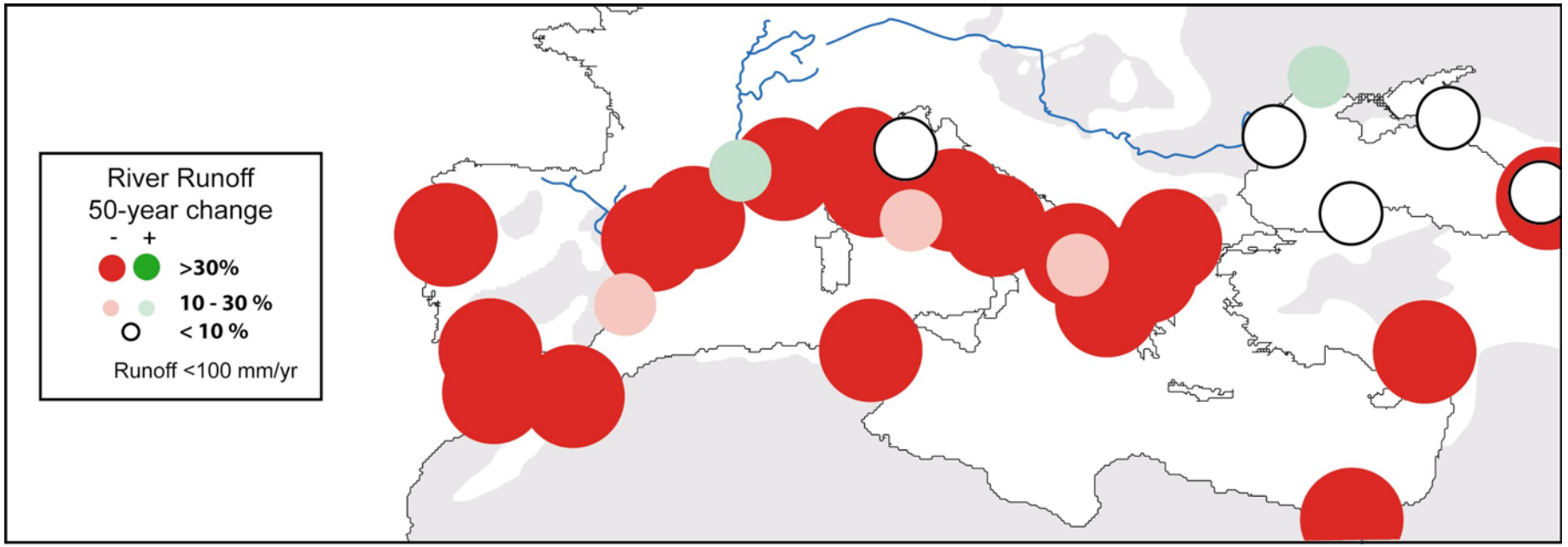

Yenisei Precipitation
Transition
Summer
Winter
Annual Winter/Transition Precipitation (mm/yr)
Lena Precipitation
Annual Summer Precipitation (mm/yr)
Yenisei Runoff
Annual Winter/Transition Runoff (mm/yr)
Lena Runoff
Annual Summer Runoff (mm/yr)
1950
1960
1970
1980
1990
2000

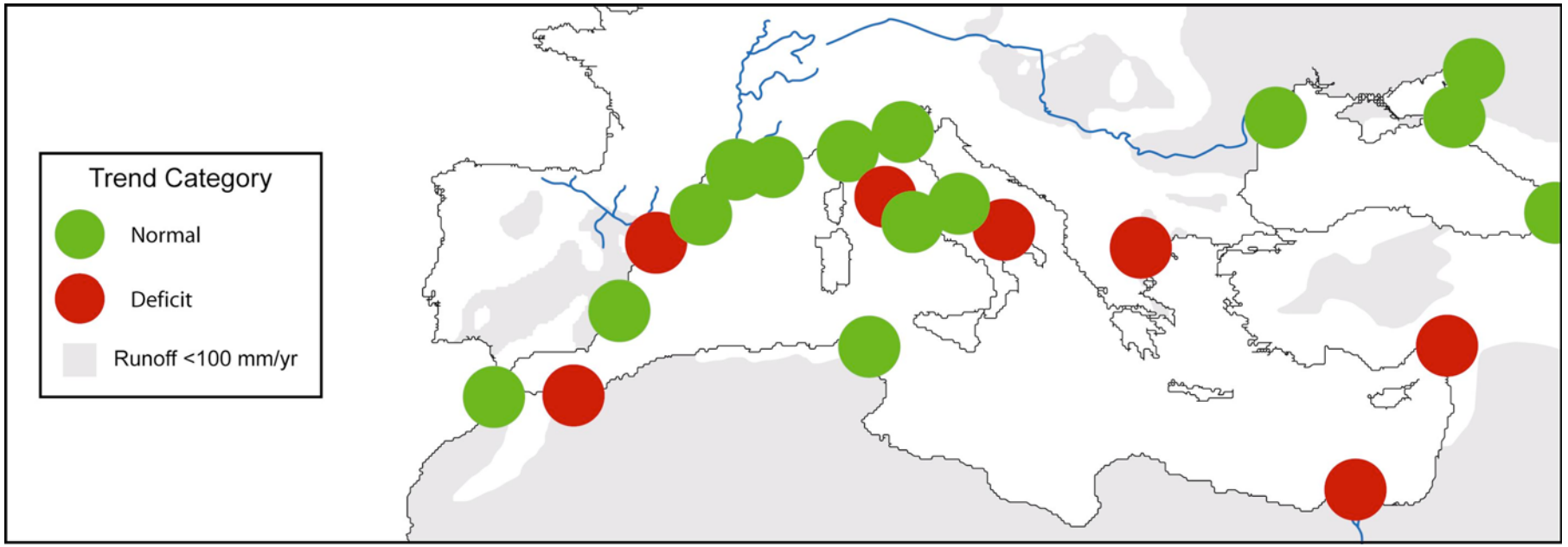
Figure 20: Retreat of the Gangotri Glacier (Garhwal Himalayas) snout during the last 220 years (Source: Jeff Kargel, USGS)

C




B
1000
100
10
1
0.1
Irrigation Index
0.1
1
10
100
Flow Regulation Index


River Runoff
50-year change
- +
>30%
10 - 30 %
< 10 %
Runoff <100 mm/yr


Trend Category
Normal
Deficit
Runoff <100 mm/yr