Evaluation of Soil Moisture in the CORe data set

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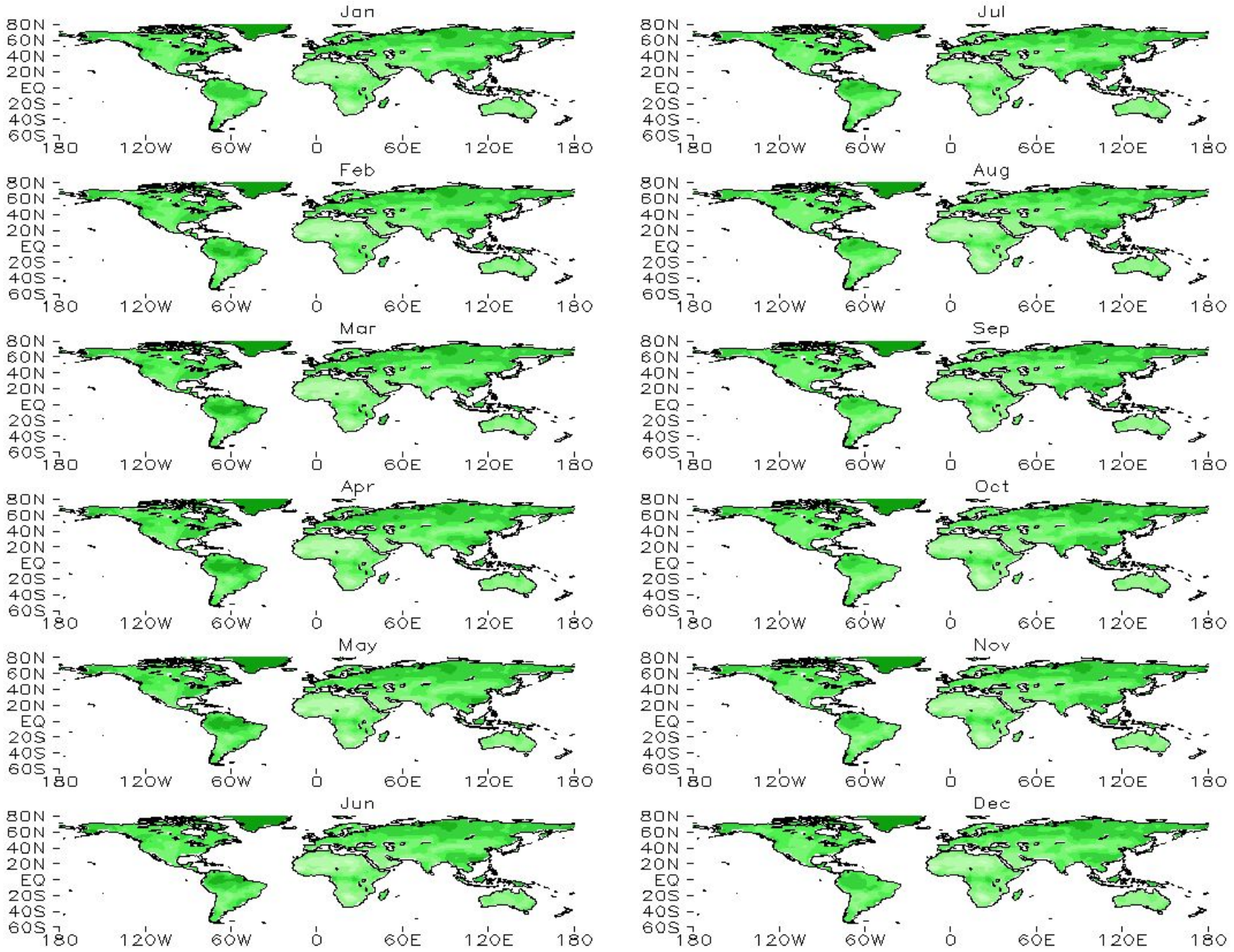
Sep, 2022

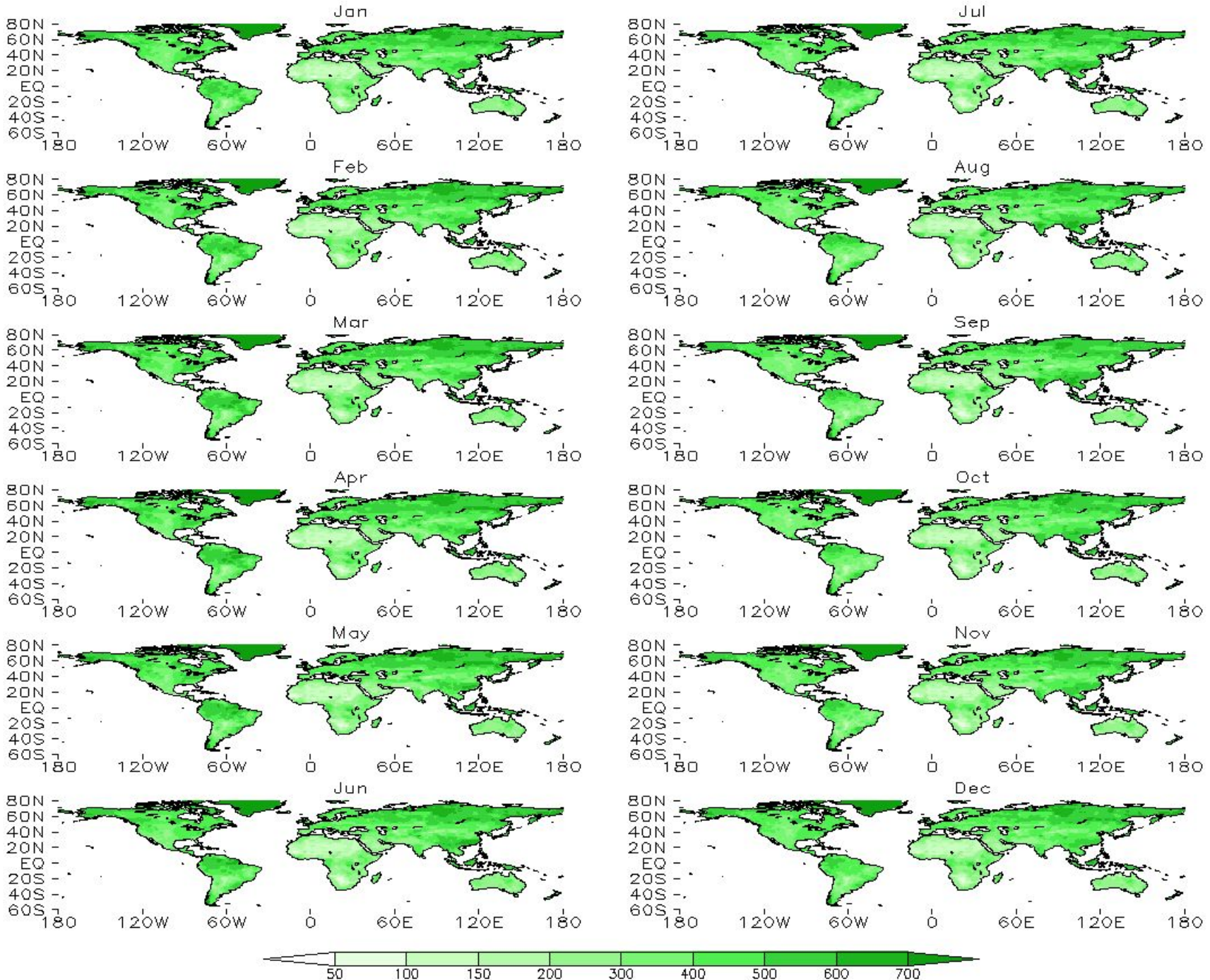
Outline

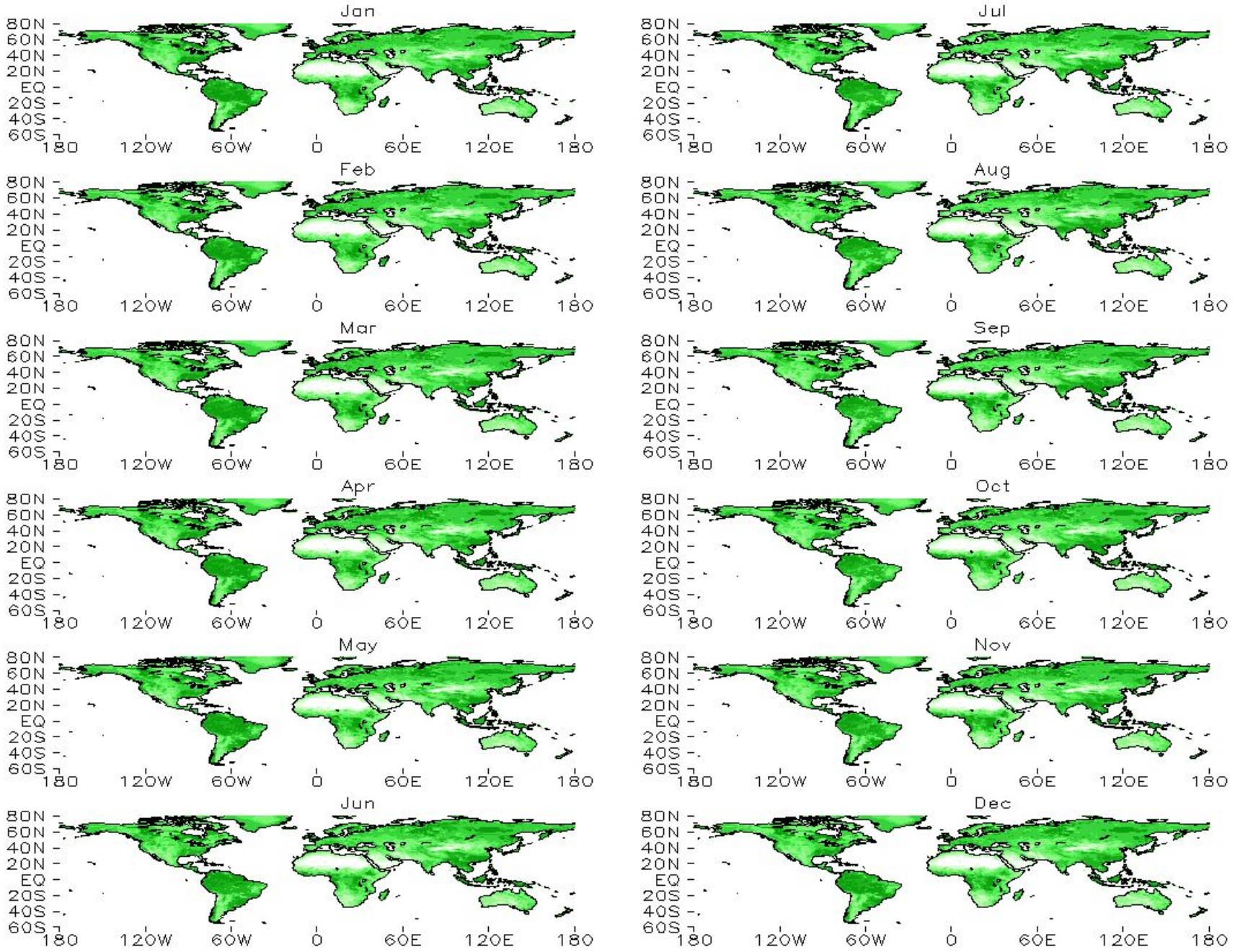
CORe, CFSR, ERA5, Leaky Bucket

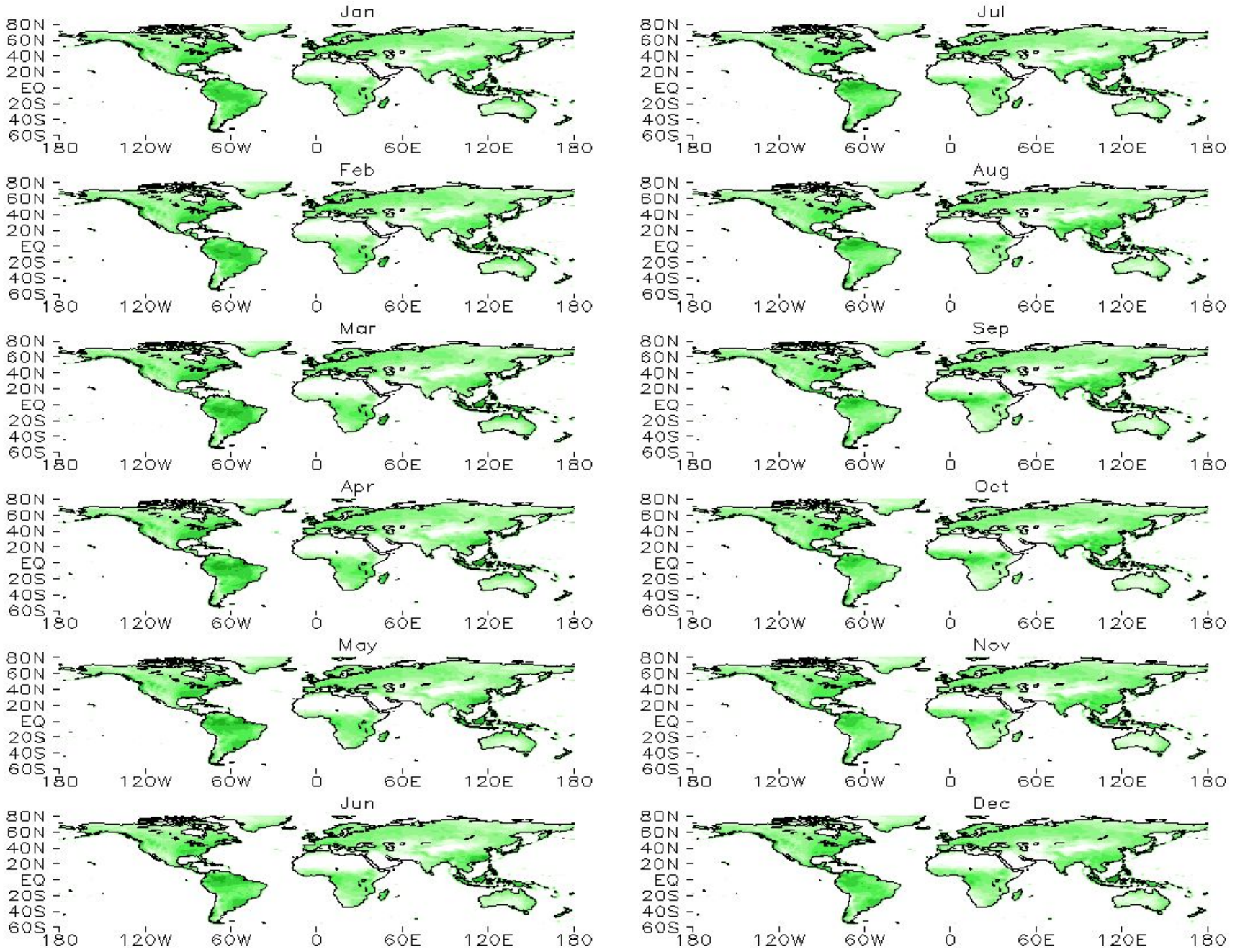
- SM Climatology
- SM Annual Range
- SM Interannual & Decadal Variations
- SM Application vs USDM: A Mutual Validation
- Summary

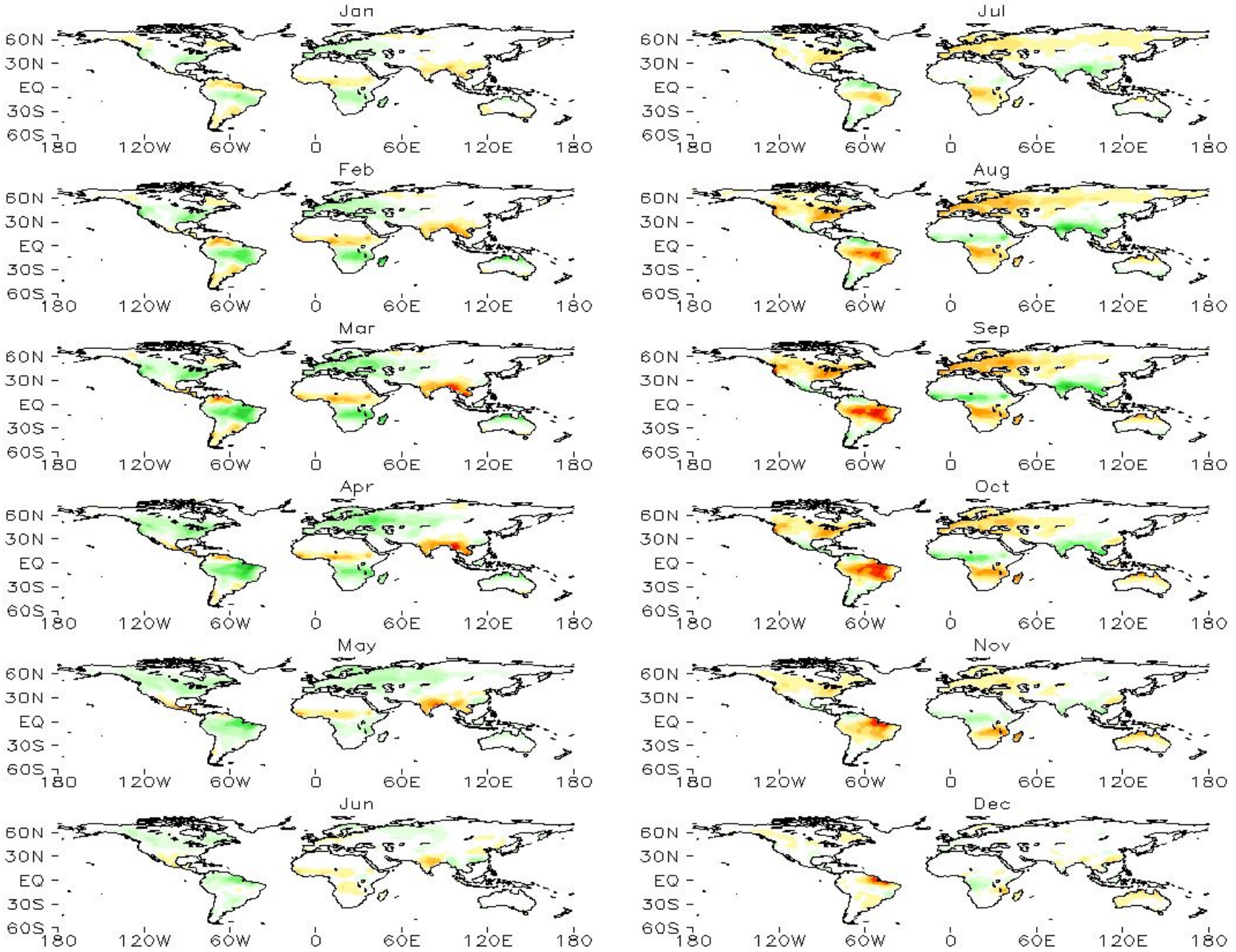
- **SM Climatology & Annual Range**

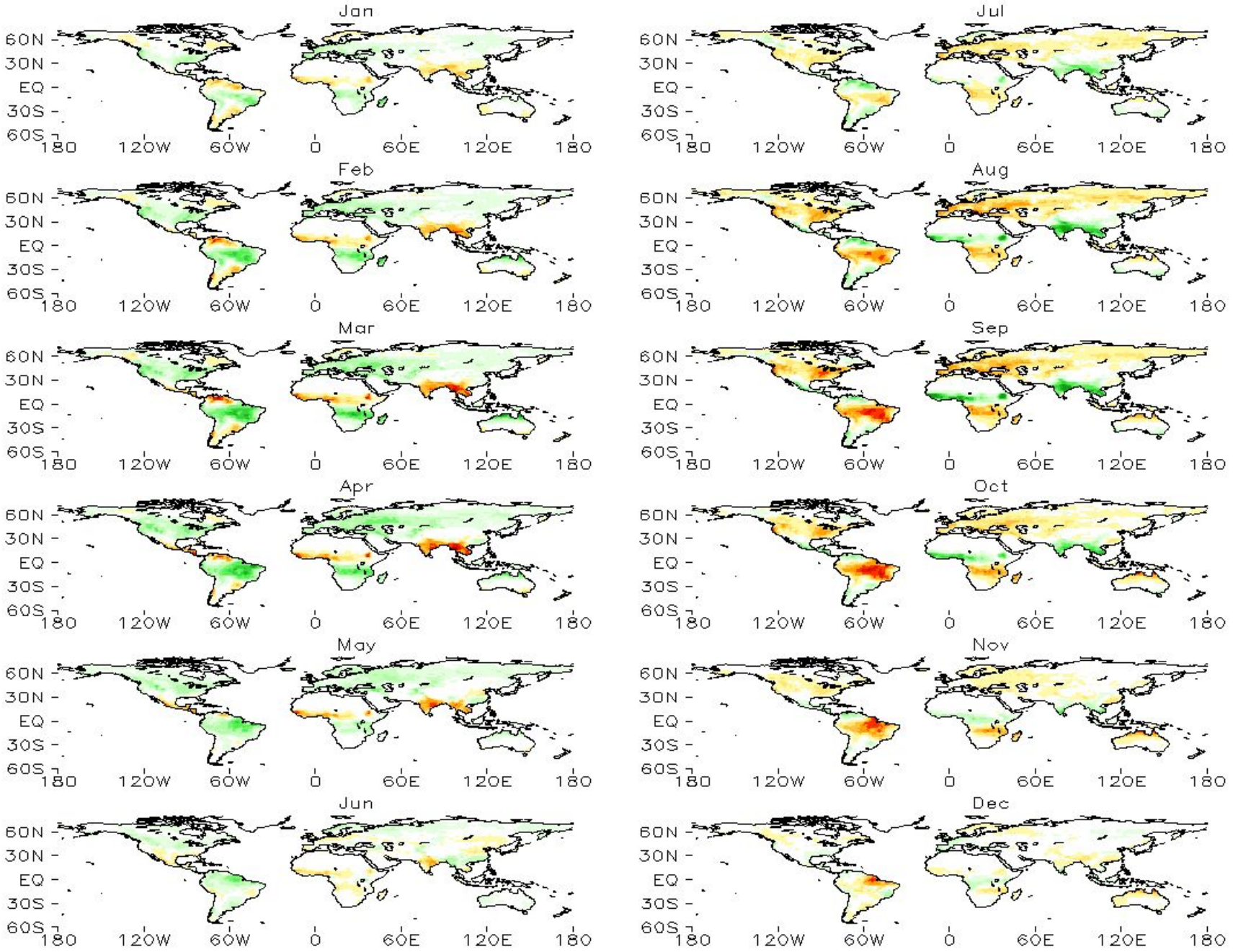

CFSR Simulated Soil Moisture Climatology (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
80N
60N
40N
20N
EQ
20S
40S
60S
180
120W
60W
0
60E
120E
180
50
100
150
200
300
400
500
600
700

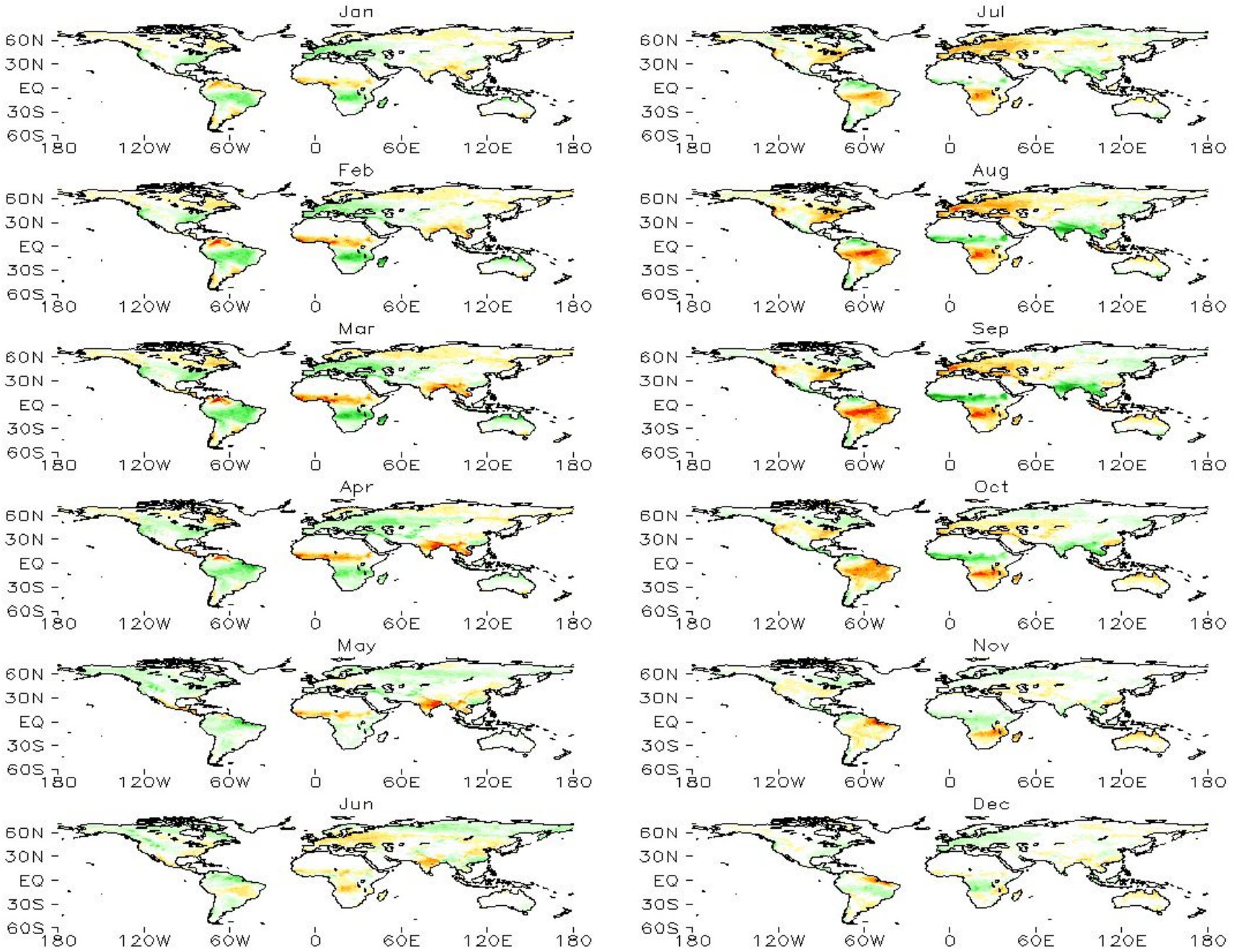

CORe Simulated Soil Moisture Climatology (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
80N
60N
40N
20N
EQ
20S
40S
60S
180
120W
60W
0
60E
120E
180
50
100
150
200
300
400
500
600
700

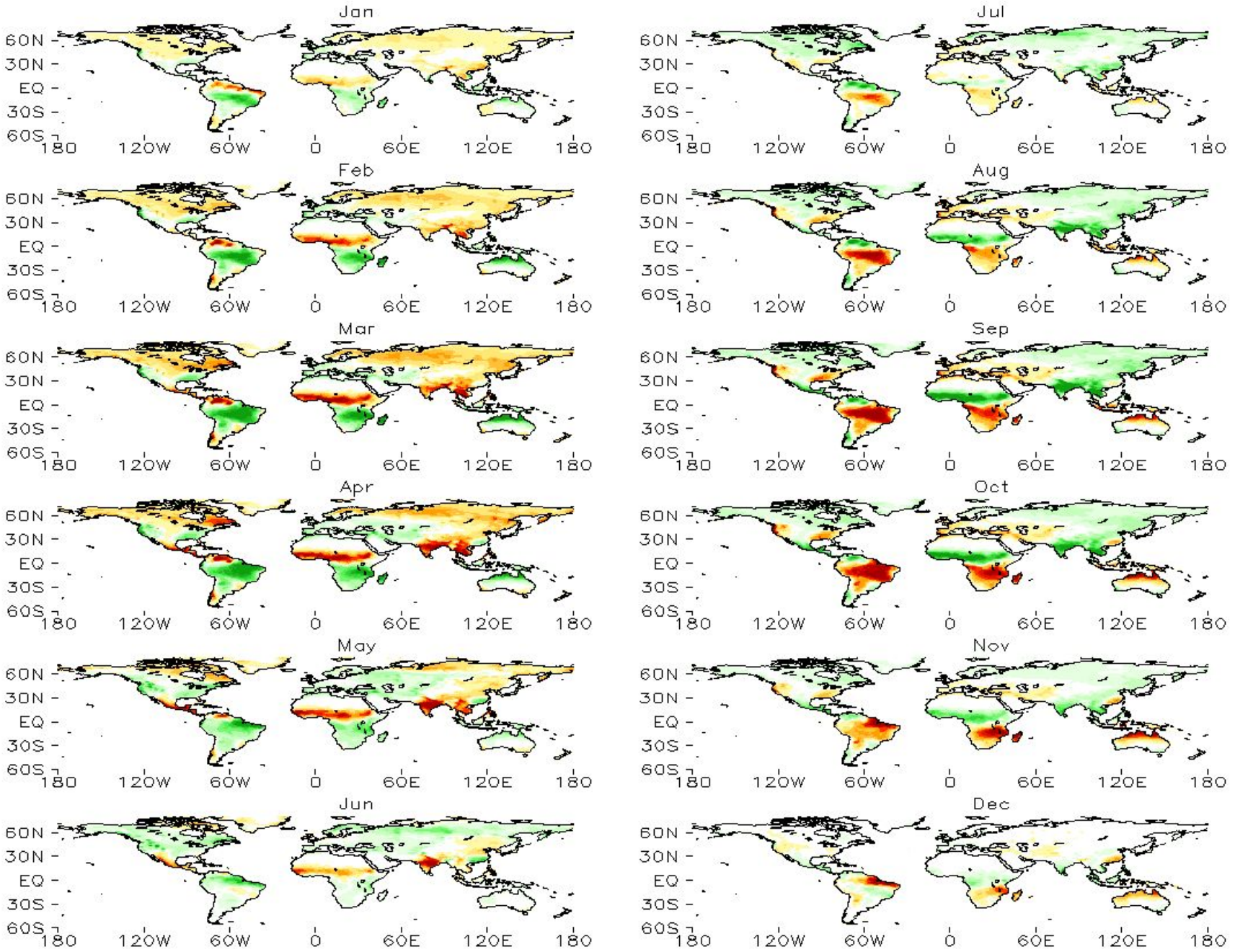

ERA5 Simulated Soil Moisture Climatology (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
80N
60N
40N
20N
EQ
20S
40S
60S
180
120W
60W
0
60E
120E
180
50
100
150
200
300
400
500
600
700


Leaky Bucket Simulated Soil Moisture Climatology (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
80N
60N
40N
20N
EQ
20S
40S
60S
180
120W
60W
0
60E
120E
180
50
100
150
200
300
400
500
600
700

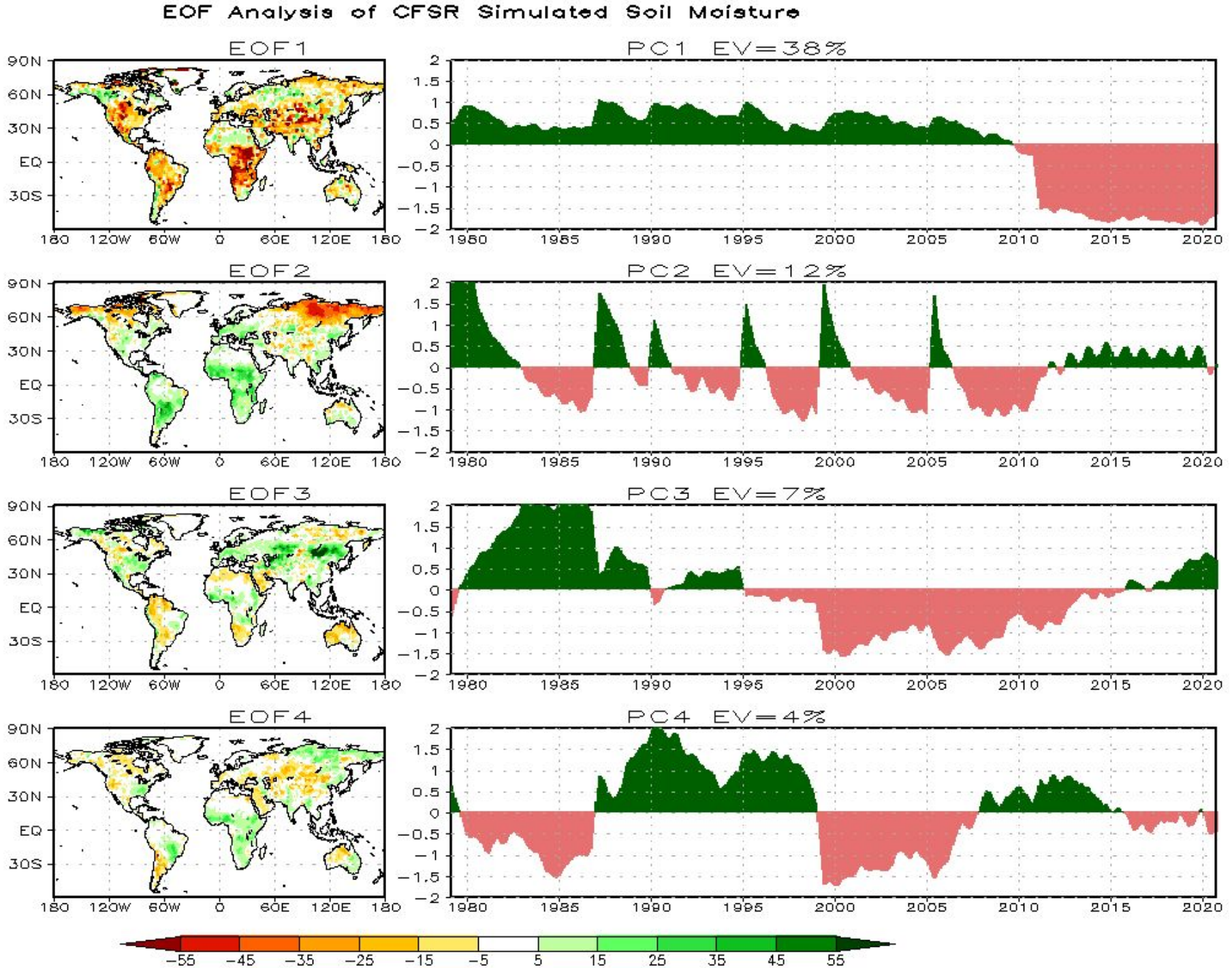

CFSR Simulated Soil Moisture Mean Annual Range (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−150 −130 −110 −90 −70 −50 −30 −10 10 30 50 70 90 110 130 150

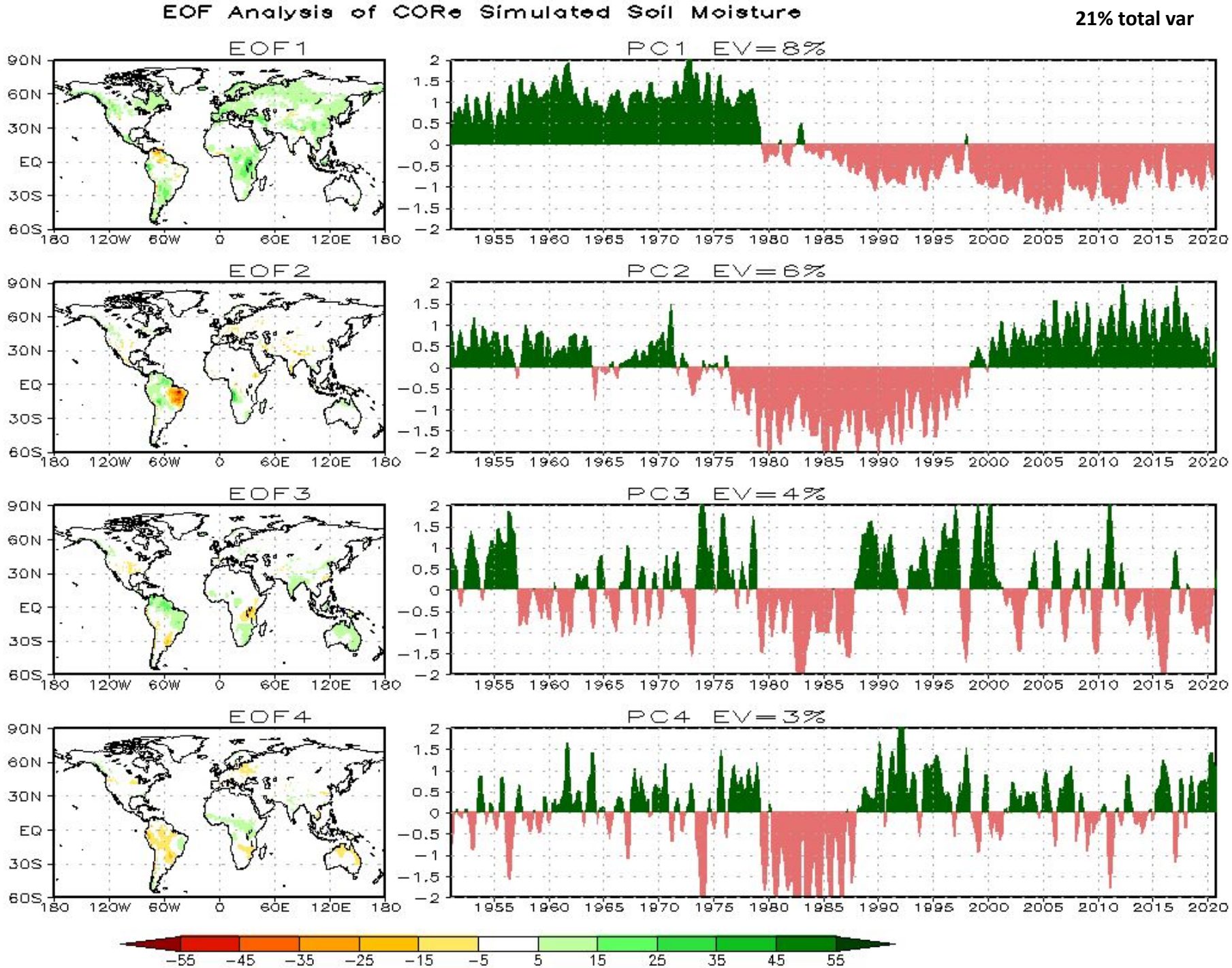

CORe Simulated Soil Moisture Mean Annual Range (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−150 −130 −110 −90 −70 −50 −30 −10 10 30 50 70 90 110 130 150

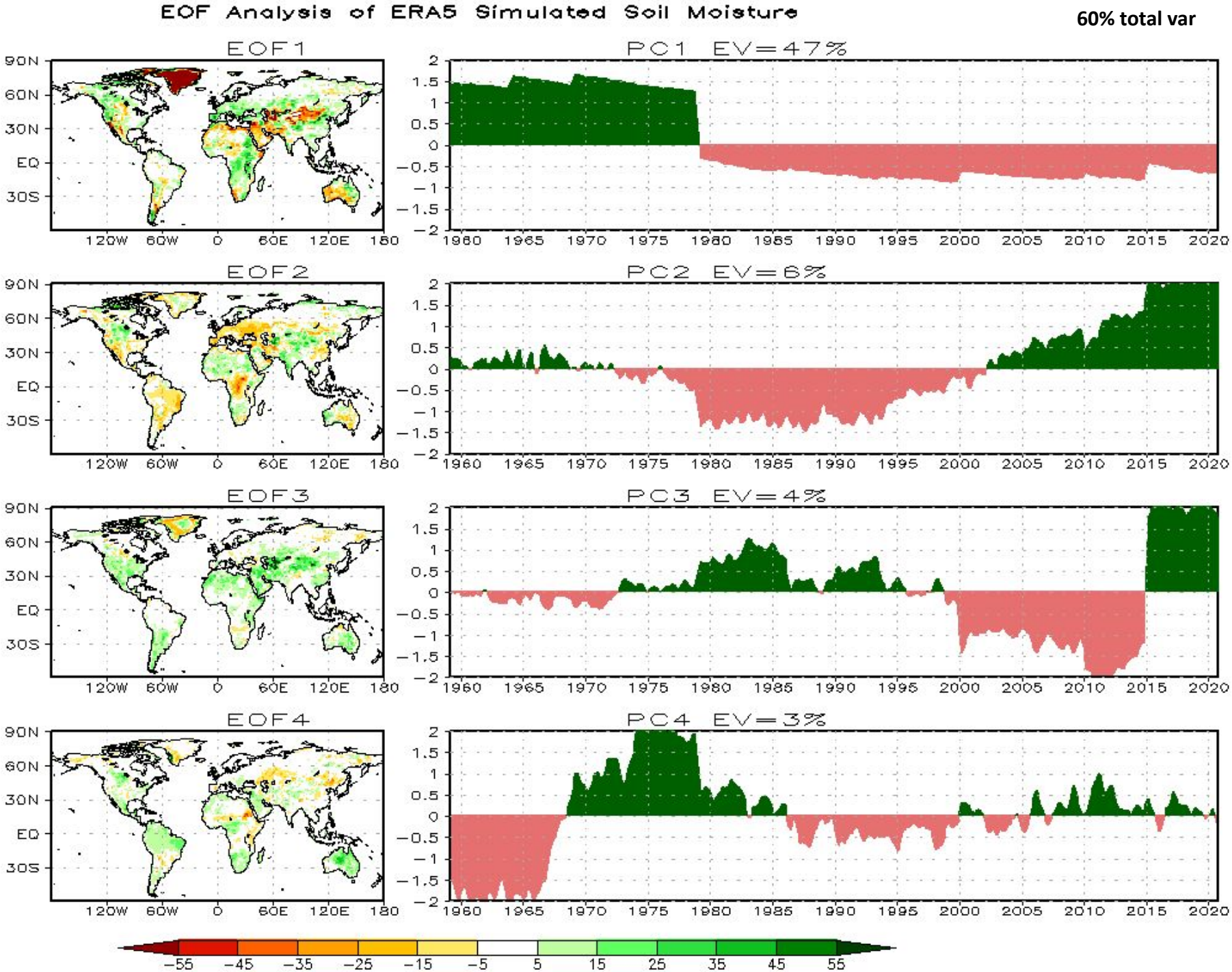

ERA5 Simulated Soil Moisture Mean Annual Range (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−150 −130 −110 −90 −70 −50 −30 −10 10 30 50 70 90 110 130 150

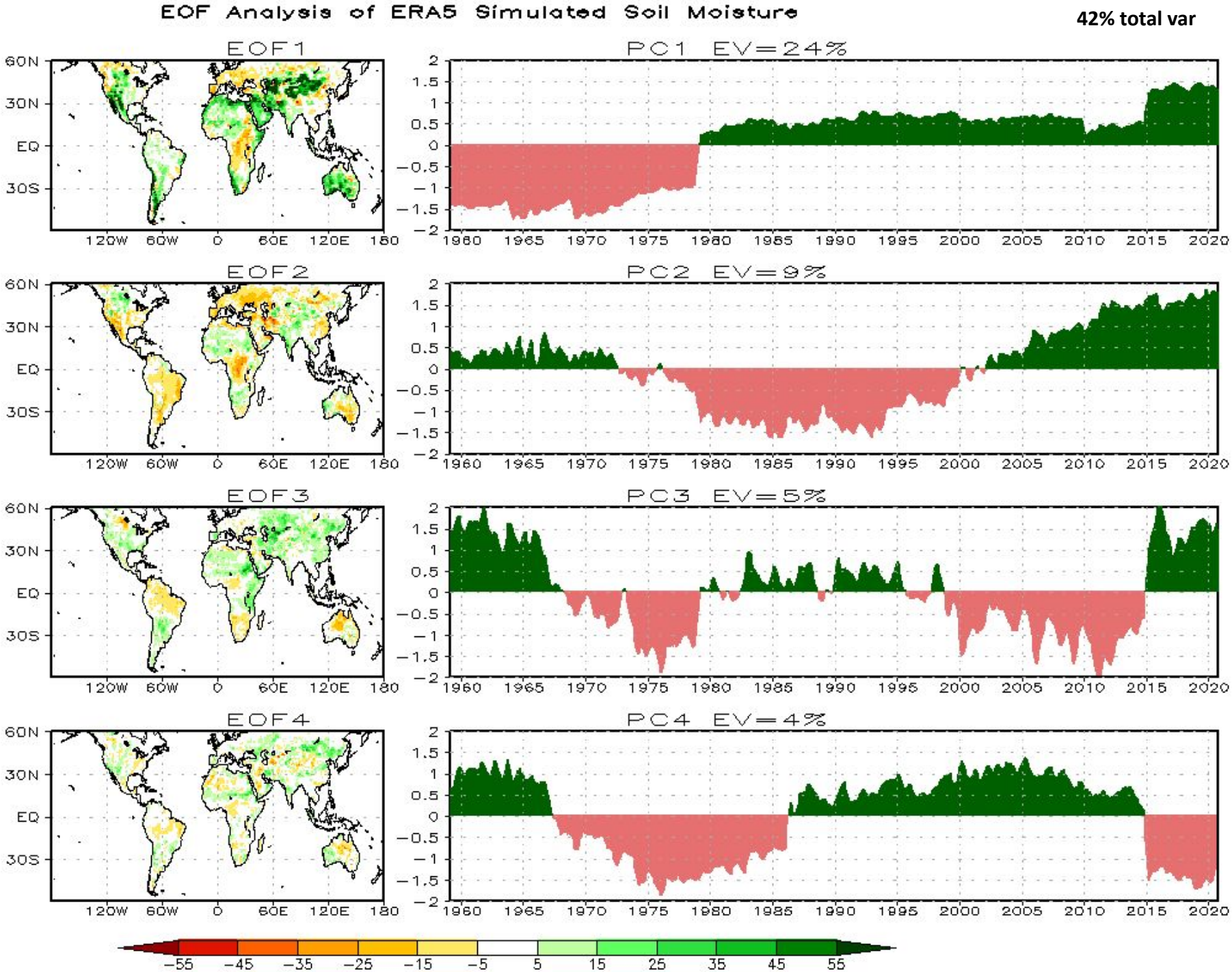

Leaky Bucket Simulated Soil Moisture Mean Annual Range (mm) (1991–2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−150 −130 −110 −90 −70 −50 −30 −10 10 30 50 70 90 110 130 150

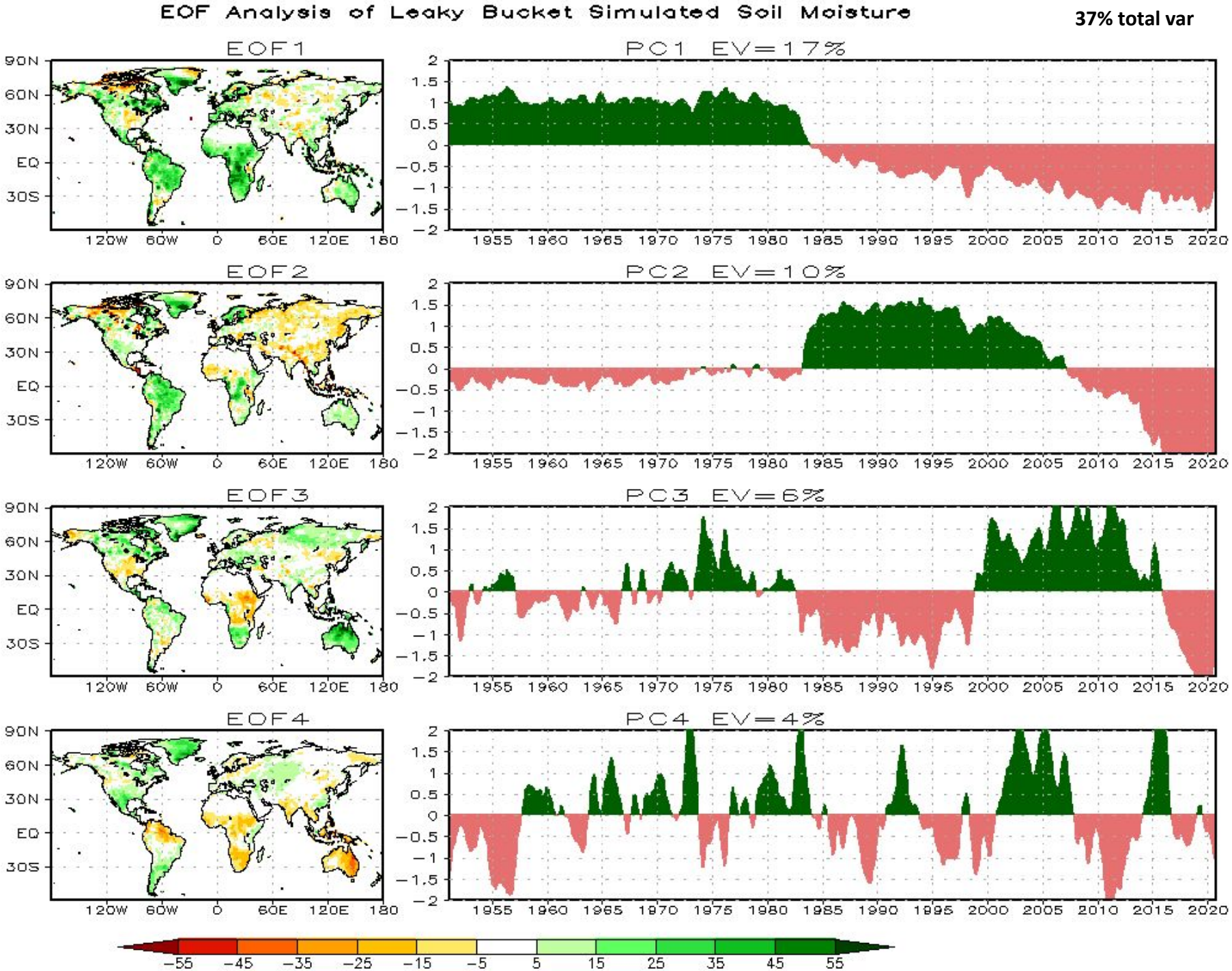
SM Interannual & Decadal Variations

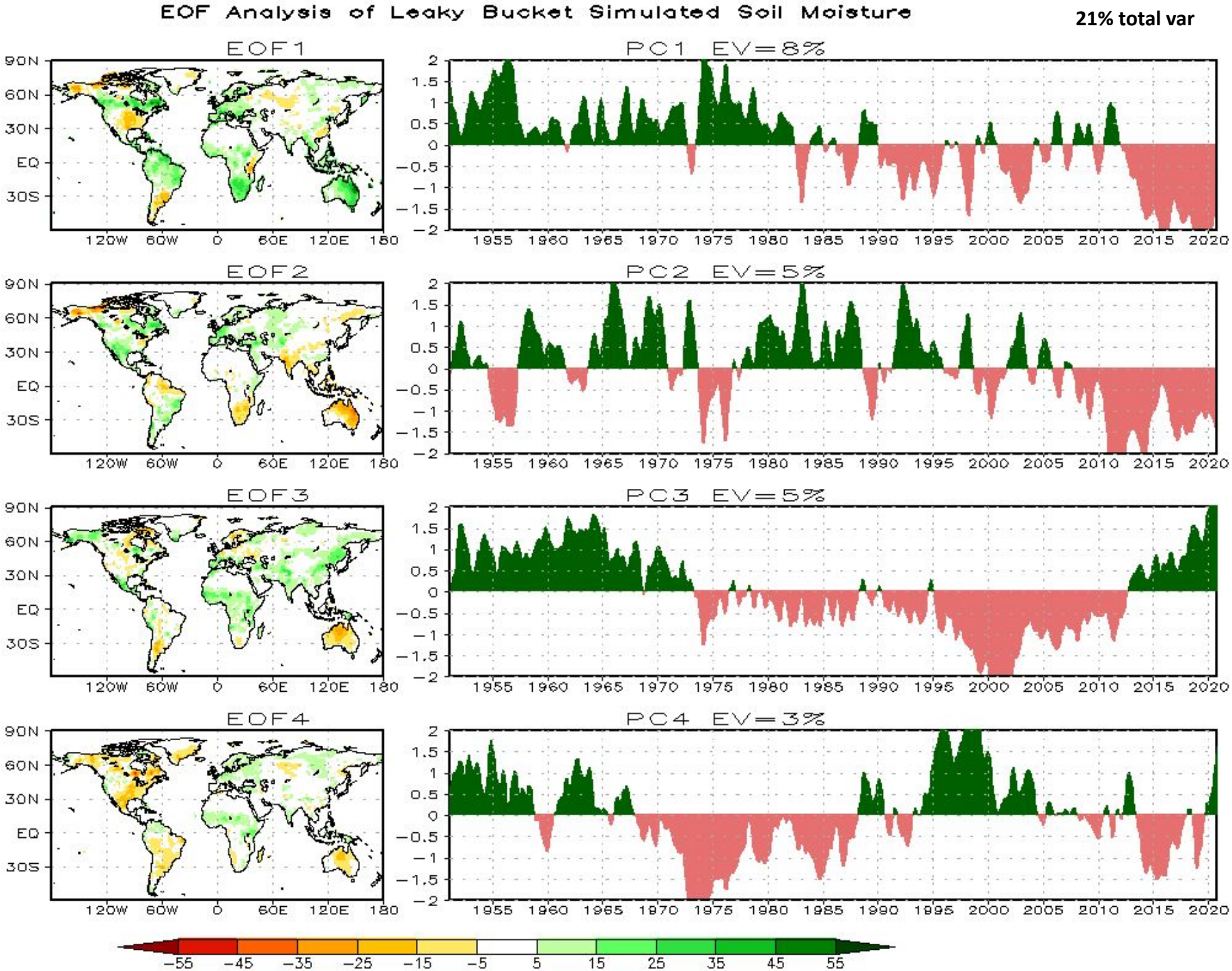

EOF Analysis of CFSR Simulated Soil Moisture
EOF1
PC1 EV=38%
EOF2
PC2 EV=12%
EOF3
PC3 EV=7%
EOF4
PC4 EV=4%
90N
60N
30N
EQ
30S
180 120W 60W 0 60E 120E 180
1980 1985 1990 1995 2000 2005 2010 2015 2020
2 1.5 1 0.5 0 −0.5 −1 −1.5 −2
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

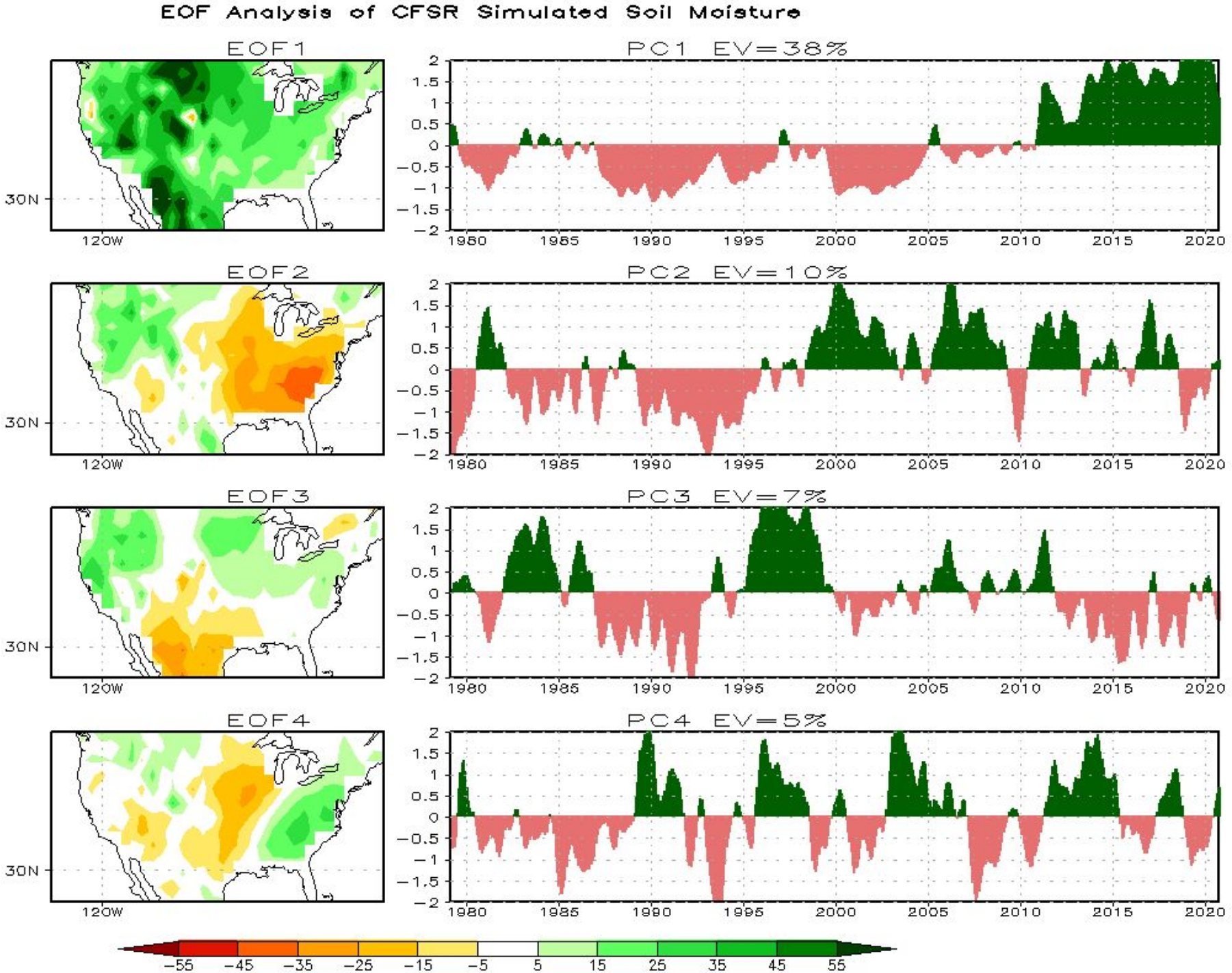

EOF Analysis of CORe Simulated Soil Moisture
21% total var
EOF1
PC1 EV=8%
EOF2
PC2 EV=6%
EOF3
PC3 EV=4%
EOF4
PC4 EV=3%
90N
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
−55
−45
−35
−25
−15
−5
5
15
25
35
45
55

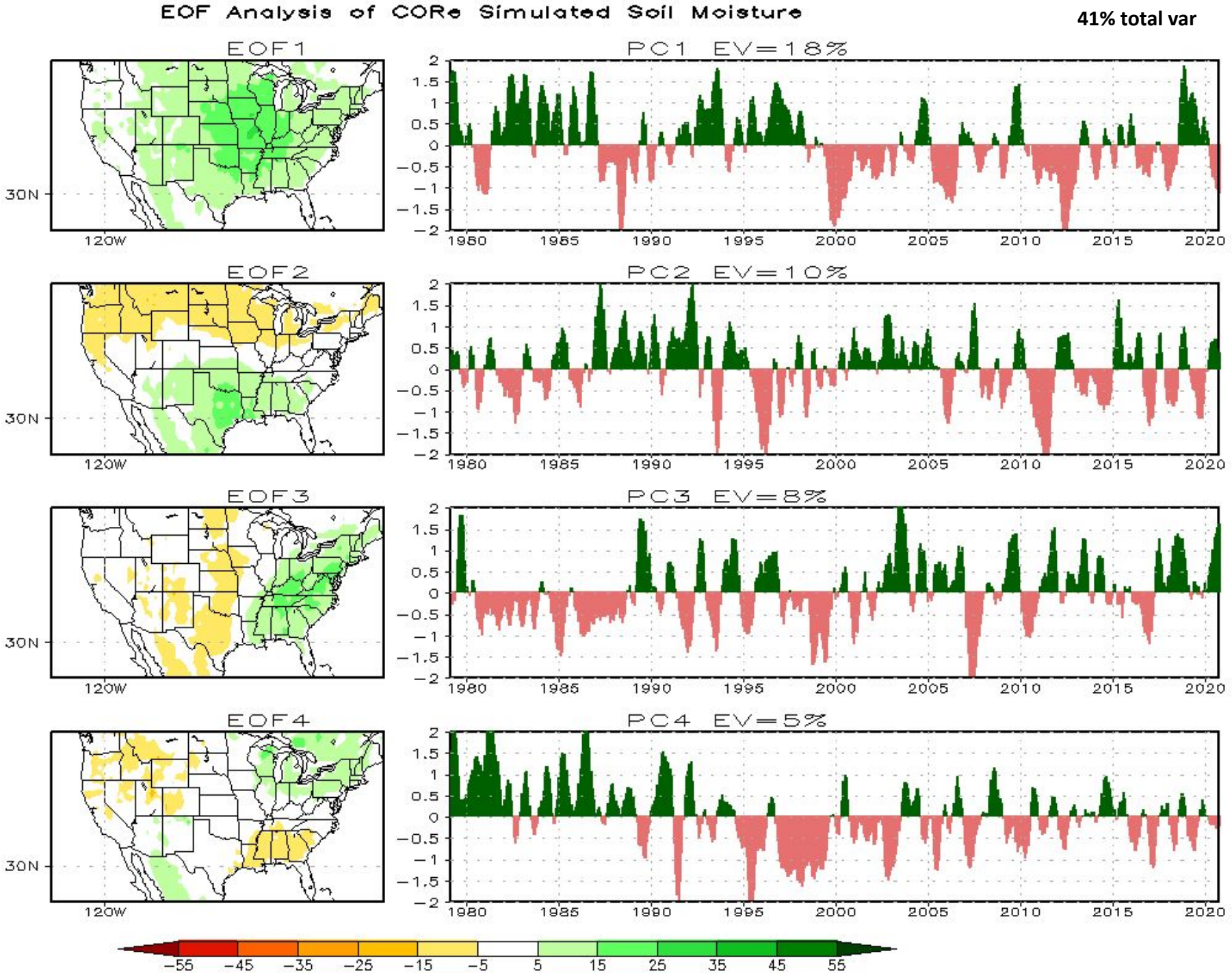

EOF Analysis of ERA5 Simulated Soil Moisture
60% total var
EOF1
PC1 EV=47%
EOF2
PC2 EV=6%
EOF3
PC3 EV=4%
EOF4
PC4 EV=3%
90N
60N
30N
EQ
30S
120W 60W 0 60E 120E 180
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
2 1.5 1 0.5 0 −0.5 −1 −1.5 −2
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

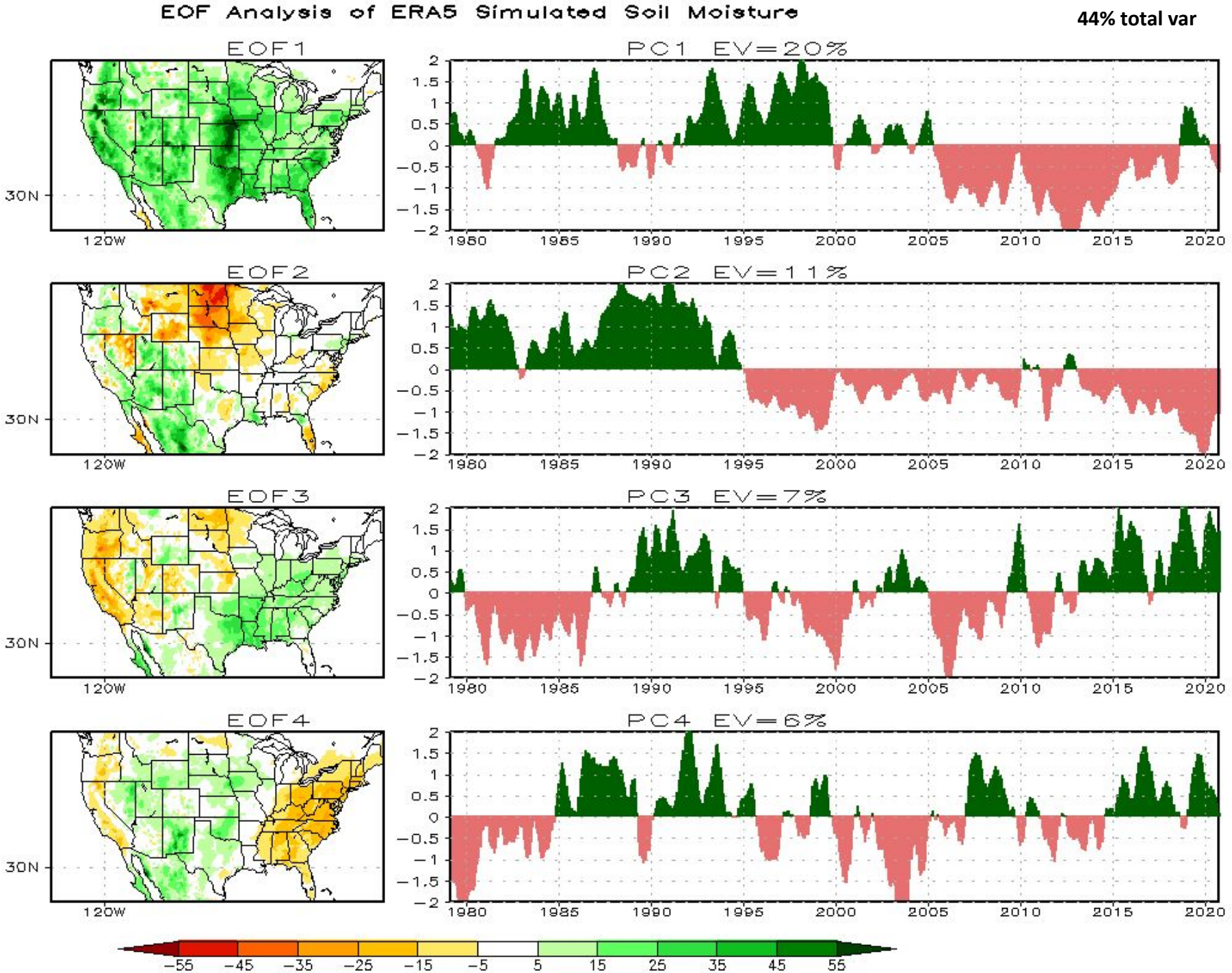

EOF Analysis of ERA5 Simulated Soil Moisture
42% total var
EOF1
PC1 EV=24%
EOF2
PC2 EV=9%
EOF3
PC3 EV=5%
EOF4
PC4 EV=4%
60N
30N
EQ
30S
120W 60W 0 60E 120E 180
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

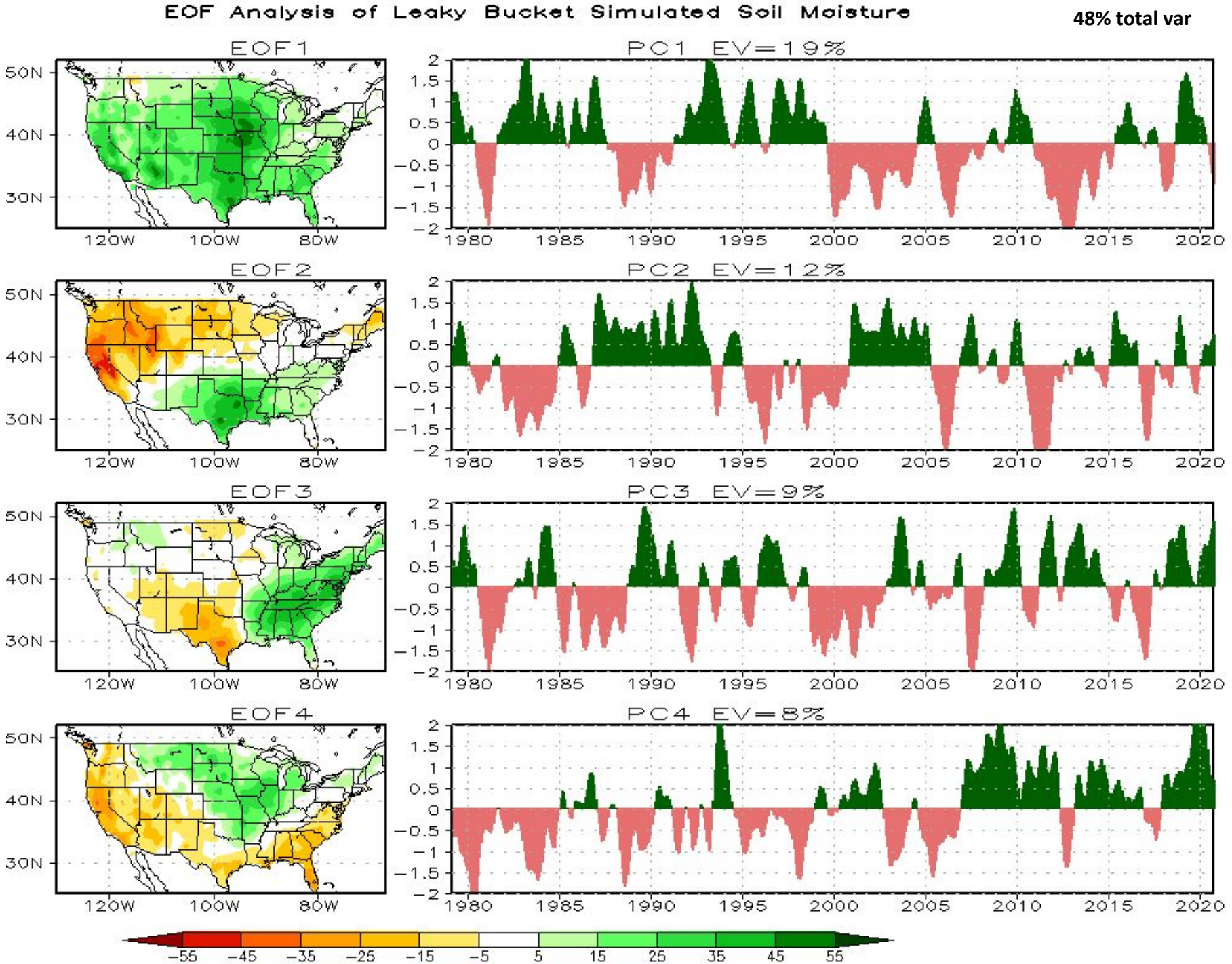

EOF Analysis of Leaky Bucket Simulated Soil Moisture
37% total var
EOF1
PC1 EV=17%
EOF2
PC2 EV=10%
EOF3
PC3 EV=6%
EOF4
PC4 EV=4%
90N
60N
30N
EQ
30S
120W 60W 0 60E 120E 180
2 1.5 1 0.5 0 −0.5 −1 −1.5 −2
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

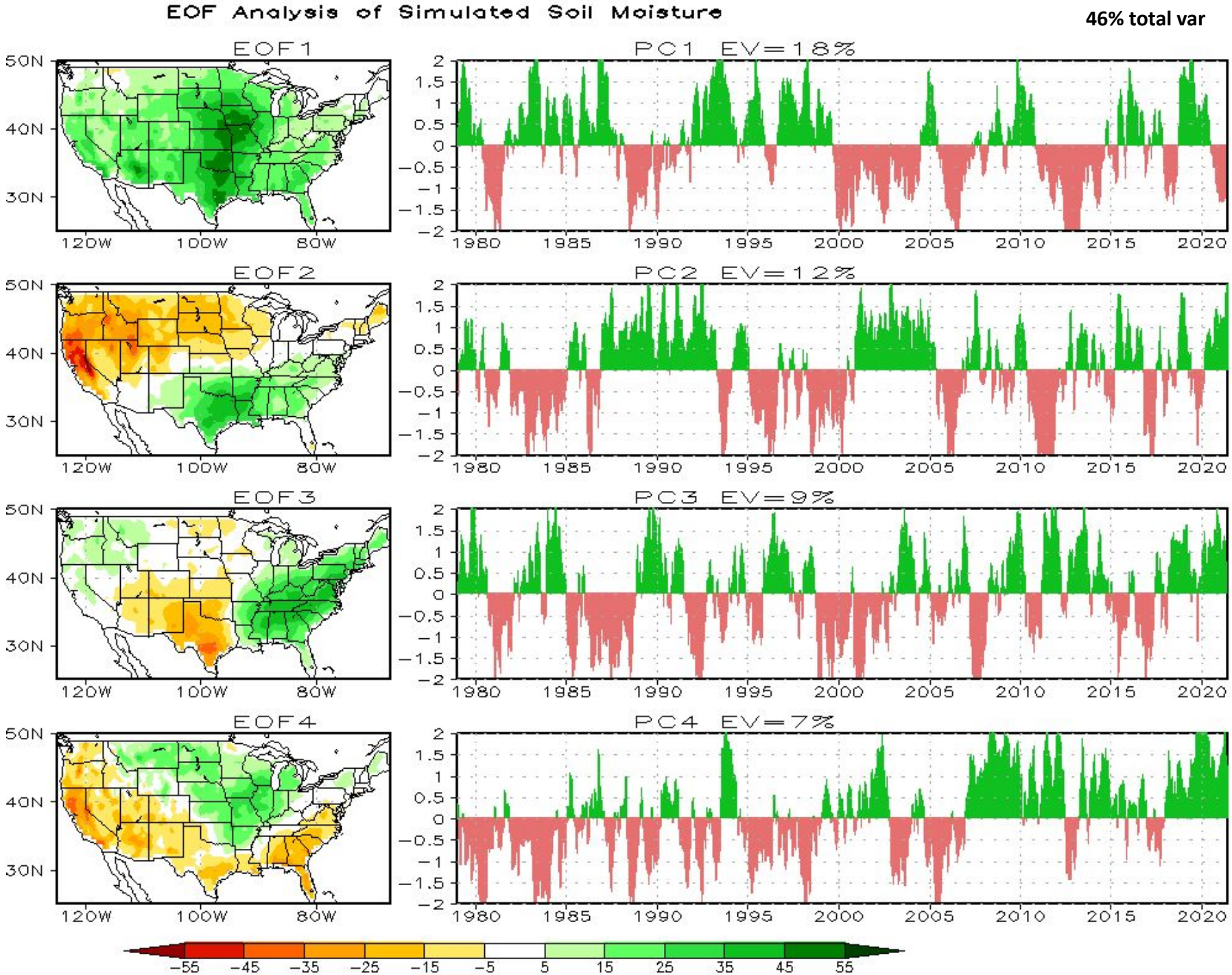

EOF Analysis of Leaky Bucket Simulated Soil Moisture
21% total var
EOF1
PC1 EV=8%
EOF2
PC2 EV=5%
EOF3
PC3 EV=5%
EOF4
PC4 EV=3%
90N
60N
30N
EQ
30S
120W 60W 0 60E 120E 180
2 1.5 1 0.5 0 −0.5 −1 −1.5 −2
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

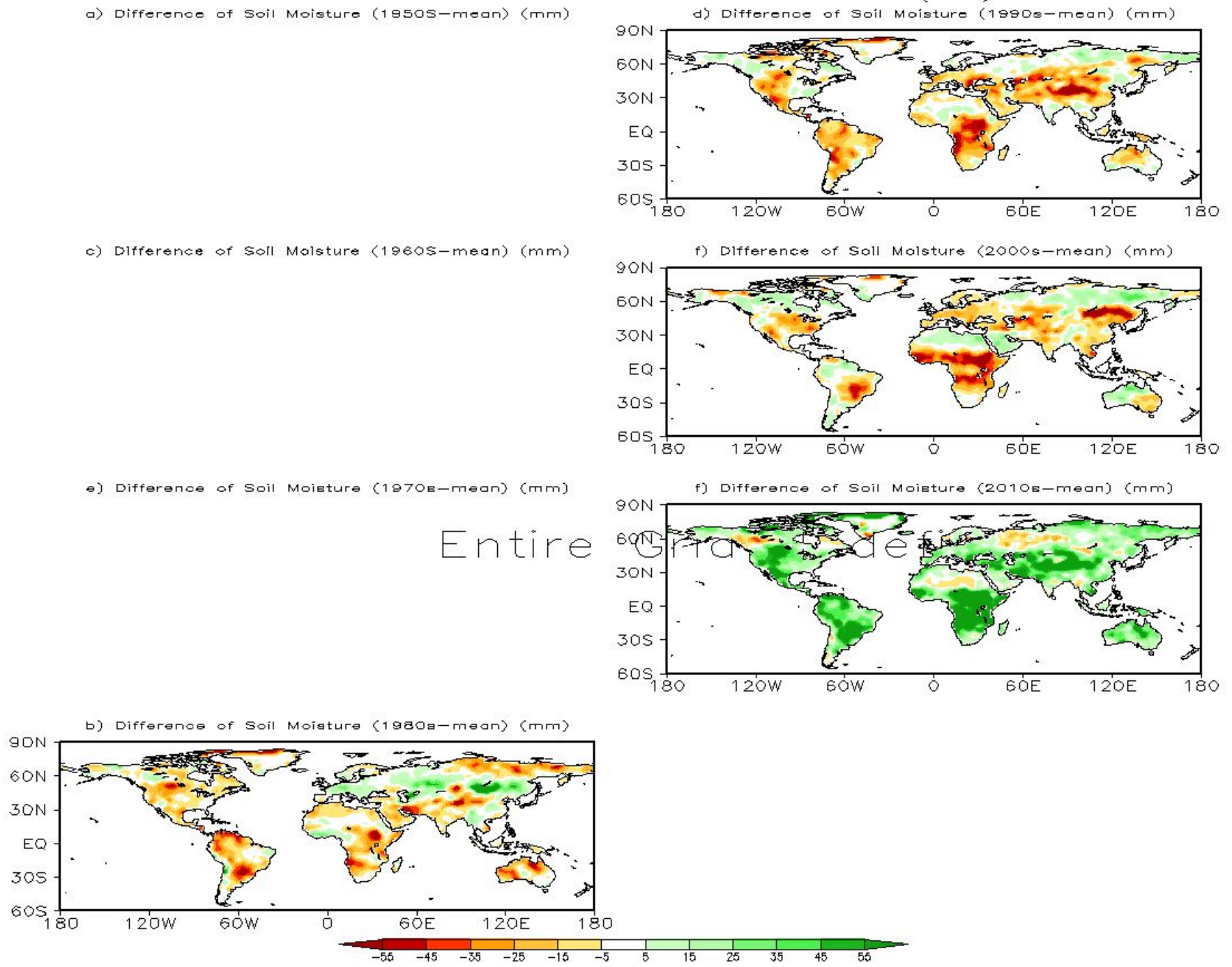

EOF Analysis of CFSR Simulated Soil Moisture
EOF1
PC1 EV=38%
EOF2
PC2 EV=10%
EOF3
PC3 EV=7%
EOF4
PC4 EV=5%
30N
120W
1980
1985
1990
1995
2000
2005
2010
2015
2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

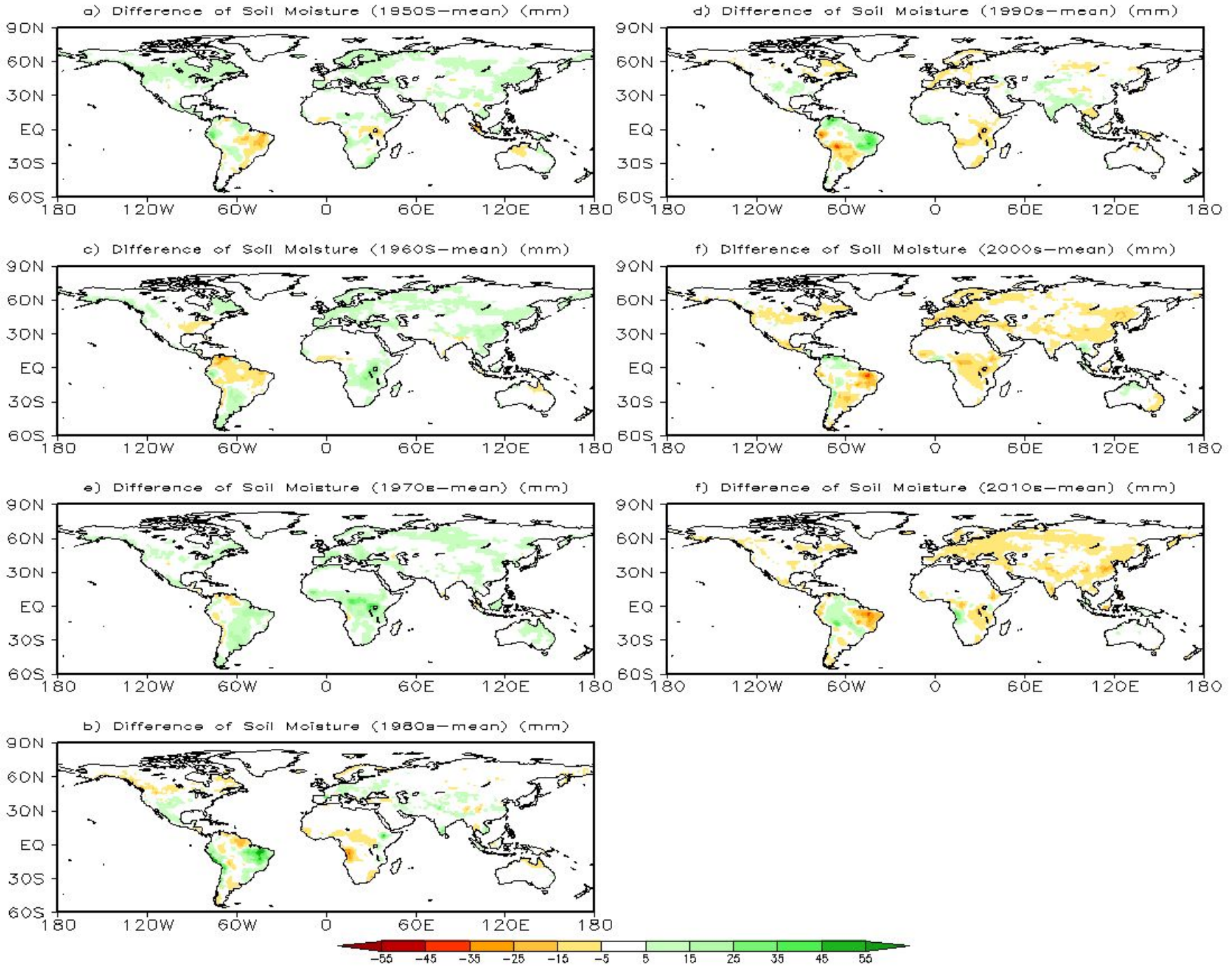

EOF Analysis of CORe Simulated Soil Moisture
41% total var
EOF1
PC1 EV=18%
EOF2
PC2 EV=10%
EOF3
PC3 EV=8%
EOF4
PC4 EV=5%
30N
120W
1980
1985
1990
1995
2000
2005
2010
2015
2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

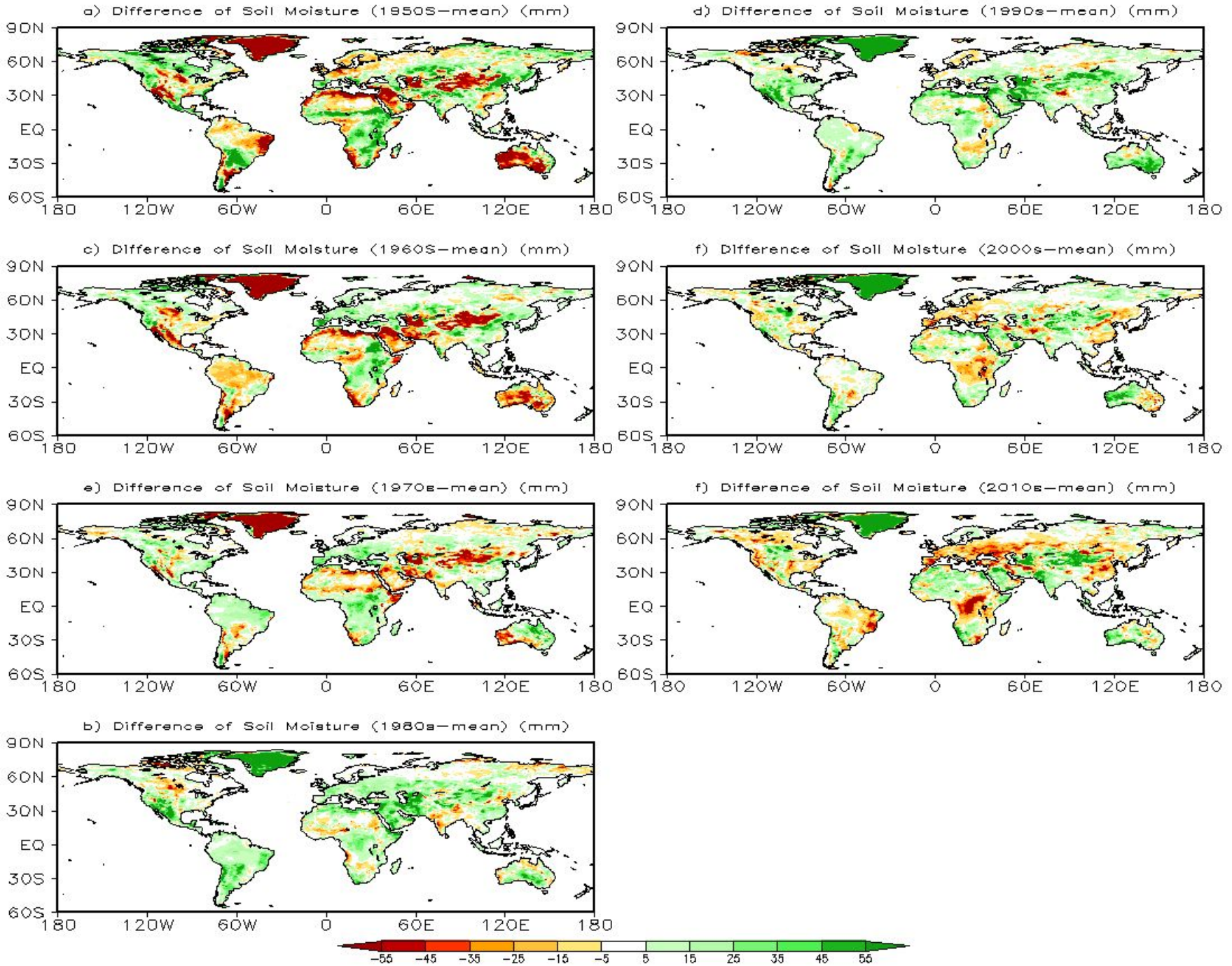

EOF Analysis of ERA5 Simulated Soil Moisture
44% total var
EOF1
PC1 EV=20%
EOF2
PC2 EV=11%
EOF3
PC3 EV=7%
EOF4
PC4 EV=6%
30N
120W
1980
1985
1990
1995
2000
2005
2010
2015
2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

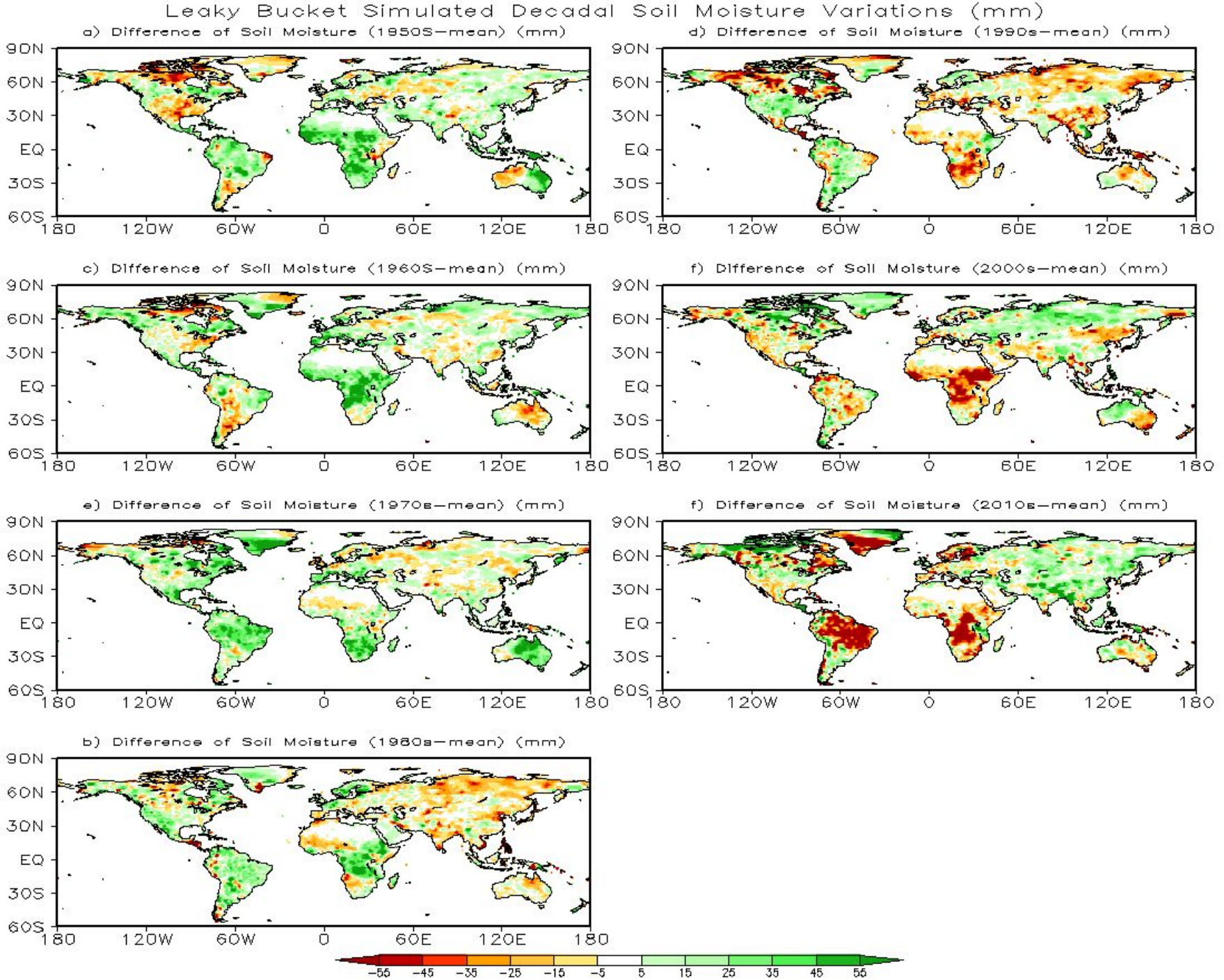

EOF Analysis of Leaky Bucket Simulated Soil Moisture
48% total var
EOF1
PC1 EV=19%
EOF2
PC2 EV=12%
EOF3
PC3 EV=9%
EOF4
PC4 EV=8%
50N
40N
30N
120W
100W
80W
1980
1985
1990
1995
2000
2005
2010
2015
2020
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

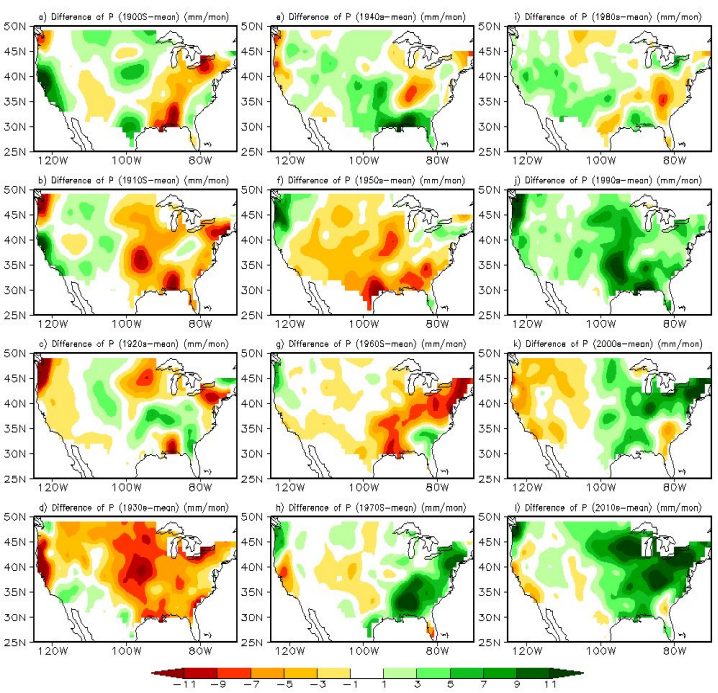

EOF Analysis of Simulated Soil Moisture
46% total var
EOF1
PC1 EV=18%
EOF2
PC2 EV=12%
EOF3
PC3 EV=9%
EOF4
PC4 EV=7%
50N
40N
30N
120W
100W
80W
1980
1985
1990
1995
2000
2005
2010
2015
2020
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−55
−45
−35
−25
−15
−5
5
15
25
35
45
55

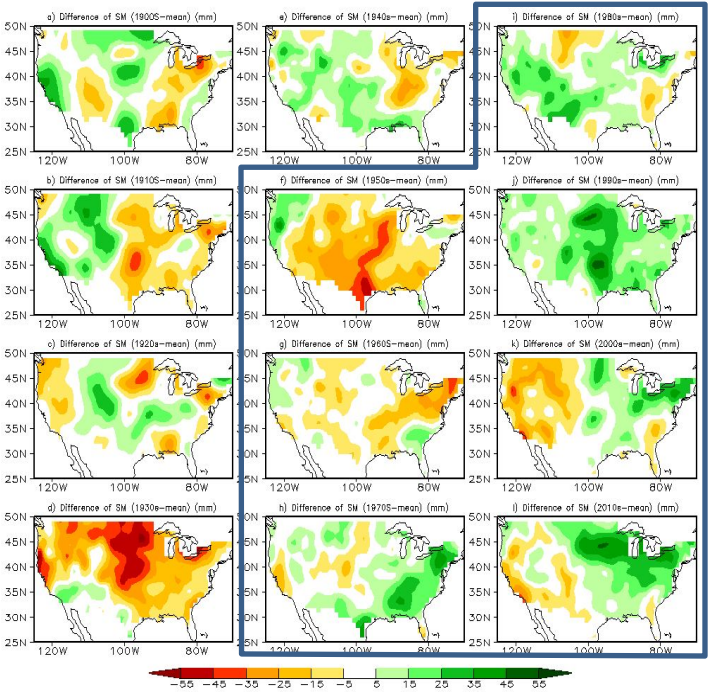

CFSR Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1950s−mean) (mm)
b) Difference of Soil Moisture (1980s−mean) (mm)
c) Difference of Soil Moisture (1960s−mean) (mm)
d) Difference of Soil Moisture (1990s−mean) (mm)
e) Difference of Soil Moisture (1970s−mean) (mm)
f) Difference of Soil Moisture (2000s−mean) (mm)
f) Difference of Soil Moisture (2010s−mean) (mm)
Entire Grid Area
90N
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

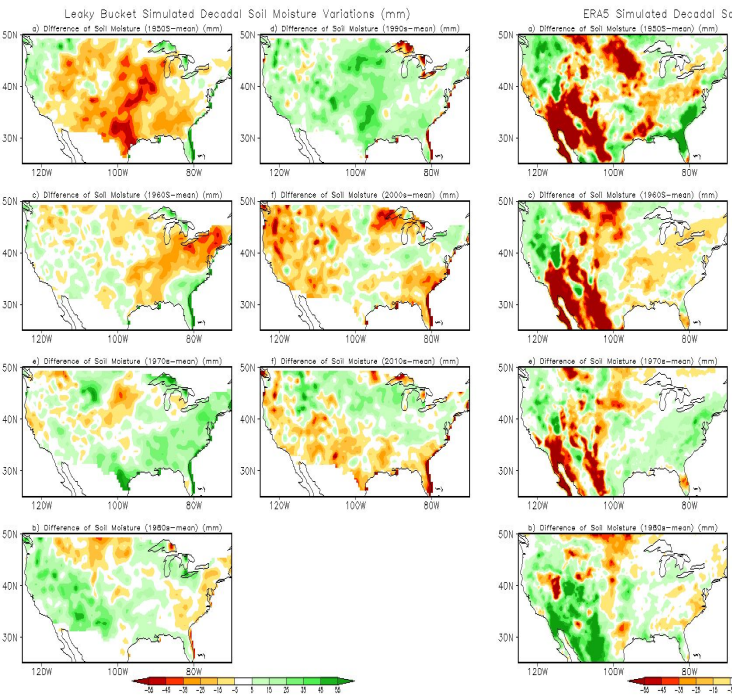

CORe Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1950s−mean) (mm)
d) Difference of Soil Moisture (1990s−mean) (mm)
c) Difference of Soil Moisture (1960s−mean) (mm)
f) Difference of Soil Moisture (2000s−mean) (mm)
e) Difference of Soil Moisture (1970s−mean) (mm)
f) Difference of Soil Moisture (2010s−mean) (mm)
b) Difference of Soil Moisture (1980s−mean) (mm)
90N
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

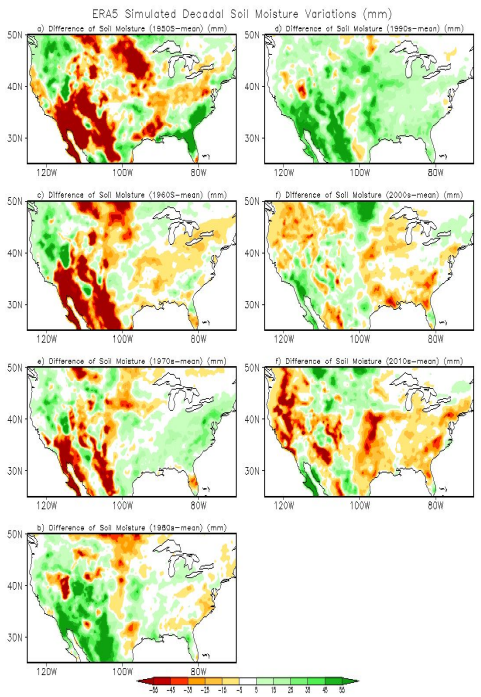

ERA5 Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1950s−mean) (mm)
d) Difference of Soil Moisture (1990s−mean) (mm)
c) Difference of Soil Moisture (1960s−mean) (mm)
f) Difference of Soil Moisture (2000s−mean) (mm)
e) Difference of Soil Moisture (1970s−mean) (mm)
f) Difference of Soil Moisture (2010s−mean) (mm)
b) Difference of Soil Moisture (1980s−mean) (mm)
90N
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

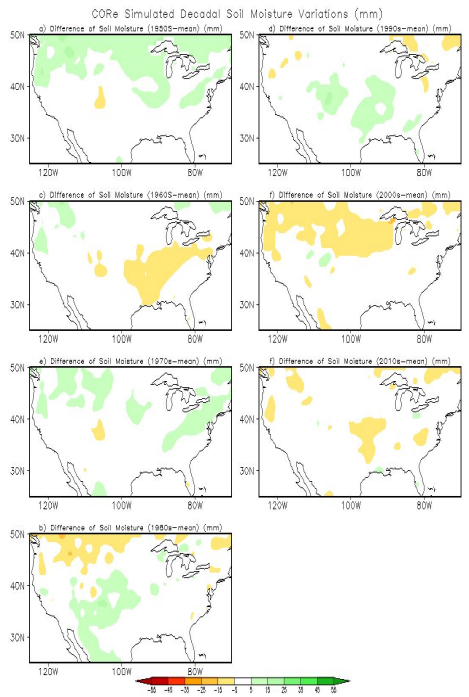

Leaky Bucket Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1950s−mean) (mm)
d) Difference of Soil Moisture (1990s−mean) (mm)
c) Difference of Soil Moisture (1960s−mean) (mm)
f) Difference of Soil Moisture (2000s−mean) (mm)
e) Difference of Soil Moisture (1970s−mean) (mm)
f) Difference of Soil Moisture (2010s−mean) (mm)
b) Difference of Soil Moisture (1980s−mean) (mm)
90N
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55

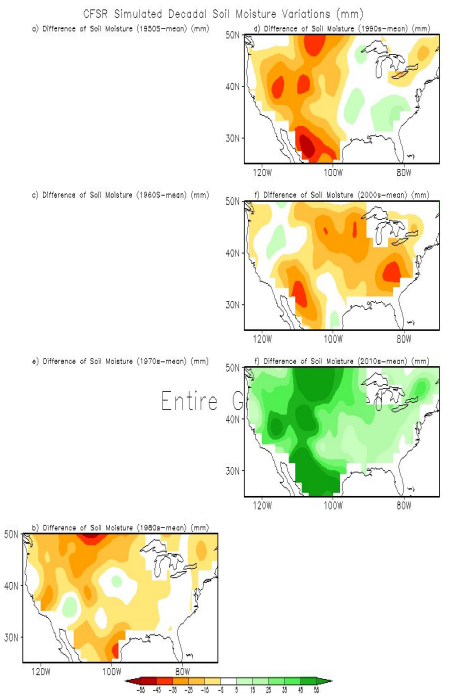

a) Difference of P (1900S–mean) (mm/mon)
e) Difference of P (1940s–mean) (mm/mon)
i) Difference of P (1980s–mean) (mm/mon)
b) Difference of P (1910S–mean) (mm/mon)
f) Difference of P (1950s–mean) (mm/mon)
j) Difference of P (1990s–mean) (mm/mon)
c) Difference of P (1920s–mean) (mm/mon)
g) Difference of P (1960S–mean) (mm/mon)
k) Difference of P (2000s–mean) (mm/mon)
d) Difference of P (1930s–mean) (mm/mon)
h) Difference of P (1970S–mean) (mm/mon)
l) Difference of P (2010s–mean) (mm/mon)
−11 −9 −7 −5 −3 −1 1 3 5 7 9 11


a) Difference of SM (1900S–mean) (mm)
e) Difference of SM (1940s–mean) (mm)
i) Difference of SM (1980s–mean) (mm)
b) Difference of SM (1910S–mean) (mm)
f) Difference of SM (1950s–mean) (mm)
j) Difference of SM (1990s–mean) (mm)
c) Difference of SM (1920s–mean) (mm)
g) Difference of SM (1960S–mean) (mm)
k) Difference of SM (2000s–mean) (mm)
d) Difference of SM (1930s–mean) (mm)
h) Difference of SM (1970S–mean) (mm)
l) Difference of SM (2010s–mean) (mm)
−55 −45 −35 −25 −15 −5 5 15 25 35 45 55


Leaky Bucket Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1900S–mean) (mm)
d) Difference of Soil Moisture (1990s–mean) (mm)
c) Difference of Soil Moisture (1960S–mean) (mm)
f) Difference of Soil Moisture (2000s–mean) (mm)
e) Difference of Soil Moisture (1970s–mean) (mm)
f) Difference of Soil Moisture (2010s–mean) (mm)
b) Difference of Soil Moisture (1980s–mean) (mm)

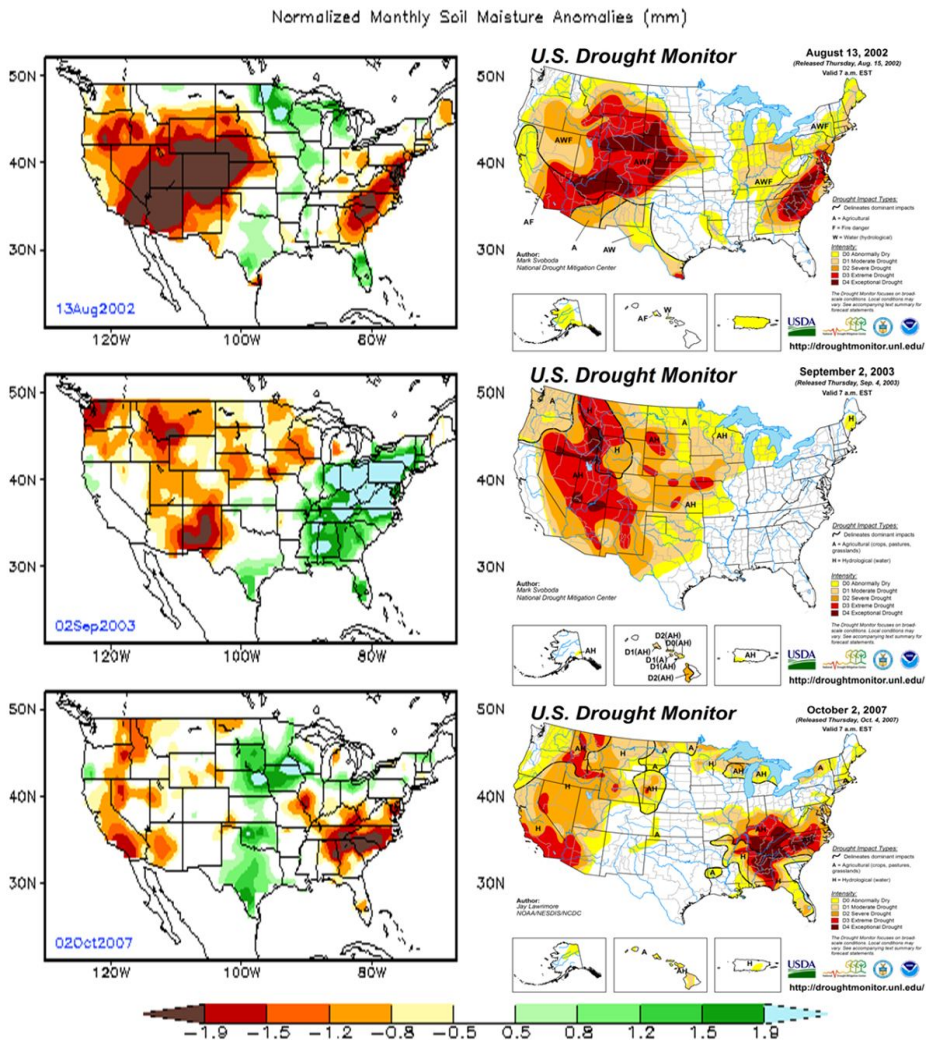

ERA5 Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1900S–mean) (mm)
d) Difference of Soil Moisture (1990s–mean) (mm)
c) Difference of Soil Moisture (1960S–mean) (mm)
f) Difference of Soil Moisture (2000s–mean) (mm)
e) Difference of Soil Moisture (1970s–mean) (mm)
f) Difference of Soil Moisture (2010s–mean) (mm)
b) Difference of Soil Moisture (1980s–mean) (mm)

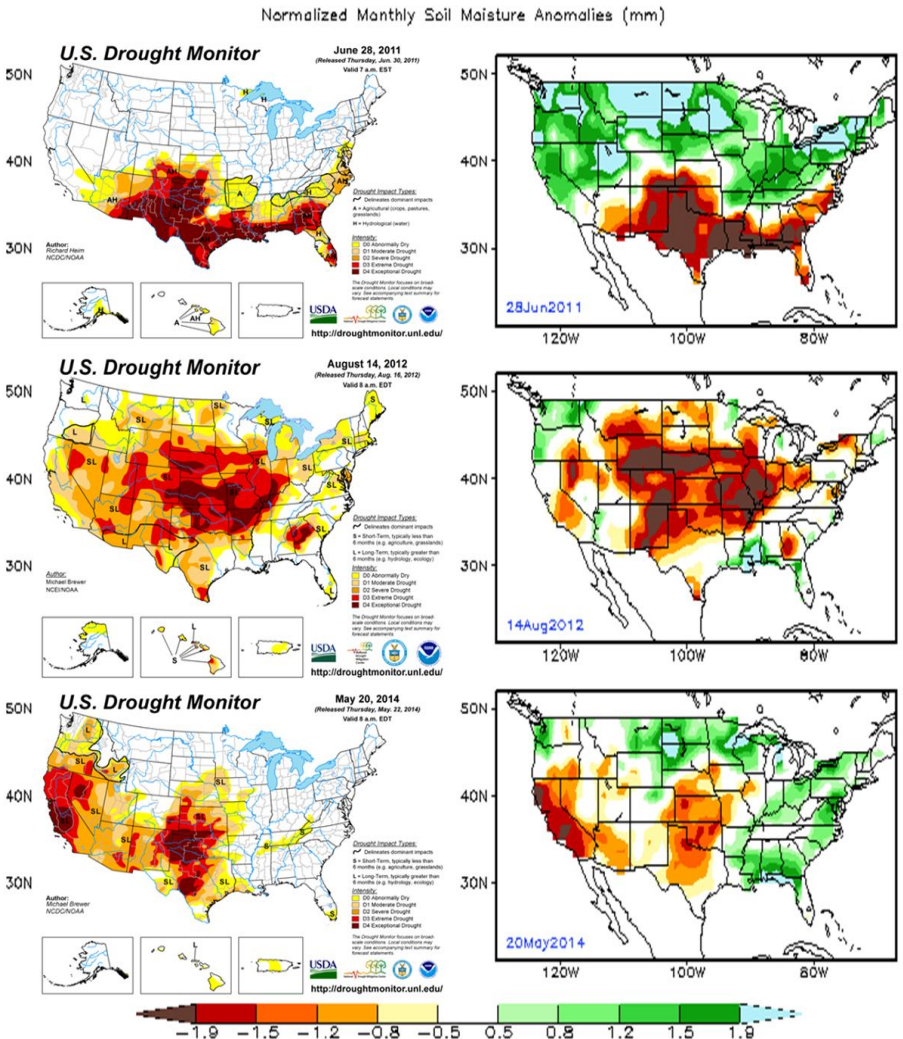

CORe Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1900S–mean) (mm)
d) Difference of Soil Moisture (1990s–mean) (mm)
c) Difference of Soil Moisture (1960S–mean) (mm)
f) Difference of Soil Moisture (2000s–mean) (mm)
e) Difference of Soil Moisture (1970s–mean) (mm)
f) Difference of Soil Moisture (2010s–mean) (mm)
b) Difference of Soil Moisture (1980s–mean) (mm)


CFSR Simulated Decadal Soil Moisture Variations (mm)
a) Difference of Soil Moisture (1900S–mean) (mm)
d) Difference of Soil Moisture (1990s–mean) (mm)
c) Difference of Soil Moisture (1960S–mean) (mm)
f) Difference of Soil Moisture (2000s–mean) (mm)
e) Difference of Soil Moisture (1970s–mean) (mm)
f) Difference of Soil Moisture (2010s–mean) (mm)
b) Difference of Soil Moisture (1980s–mean) (mm)

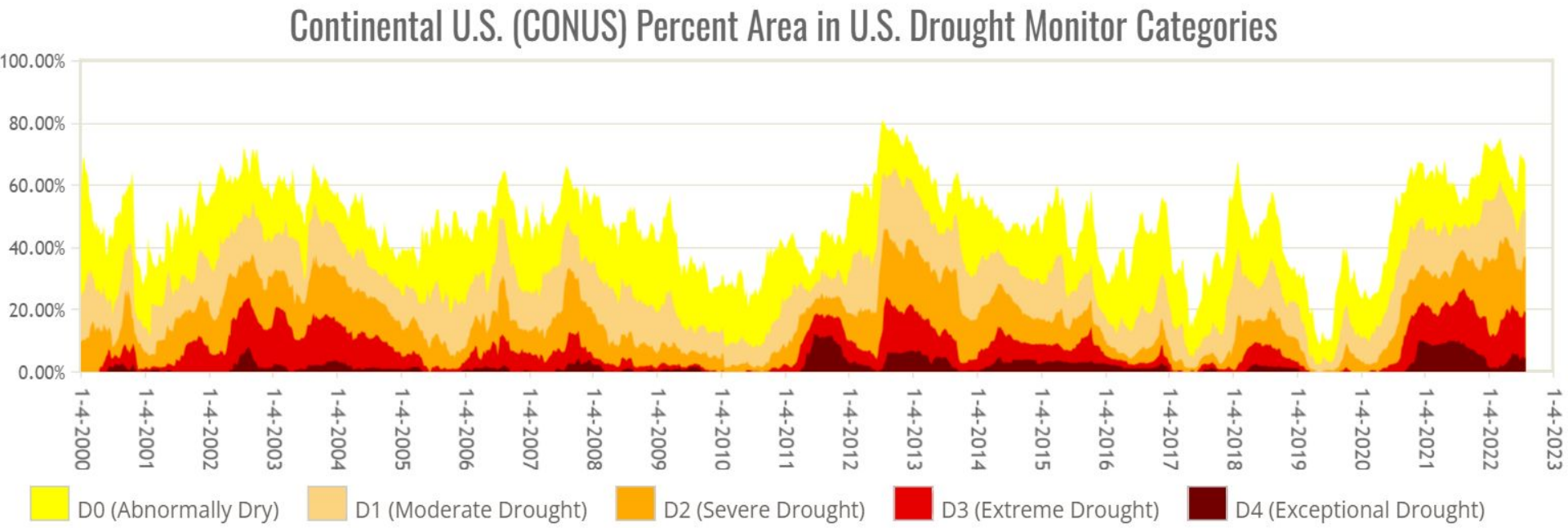
SM Application vs US Drought Monitor (USDM)

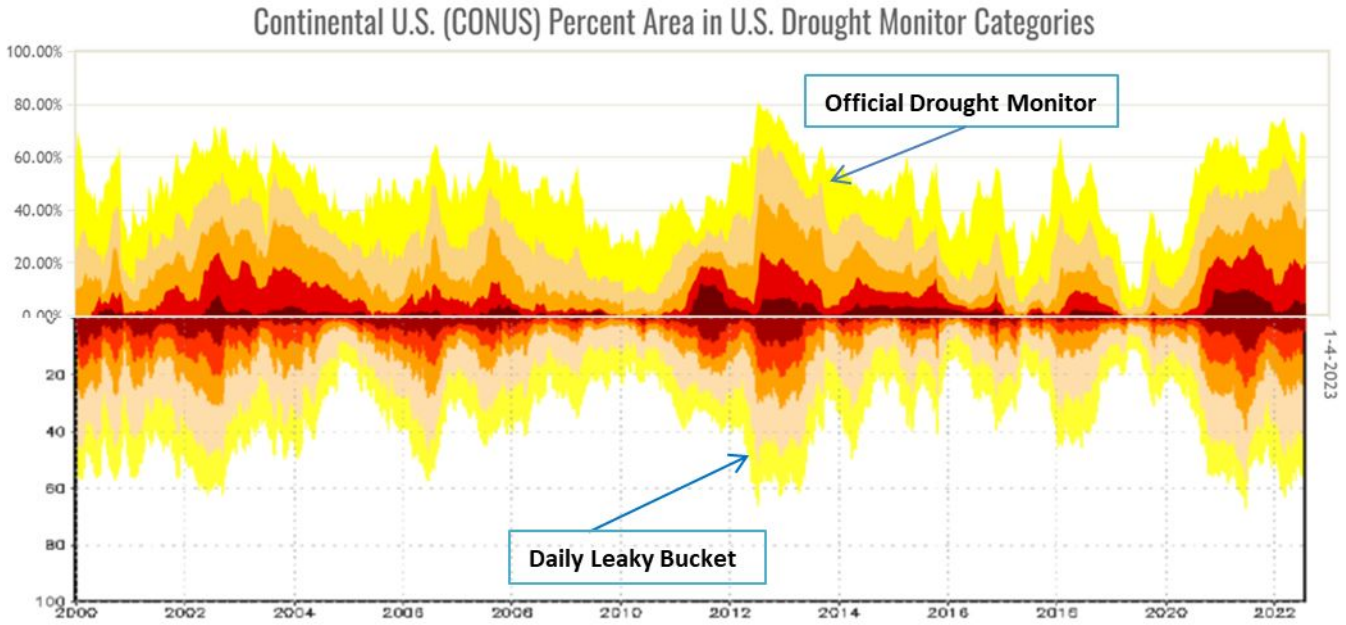
A Mutual Validation

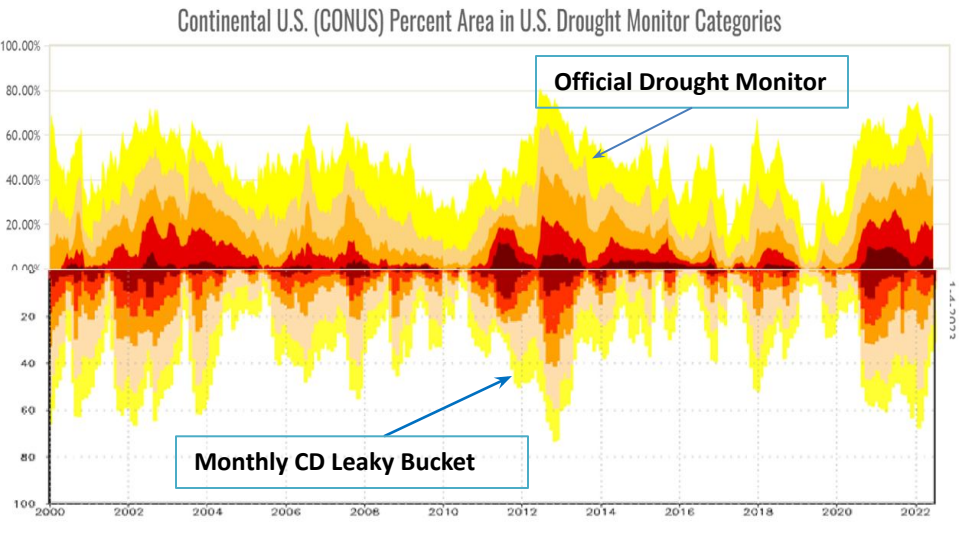


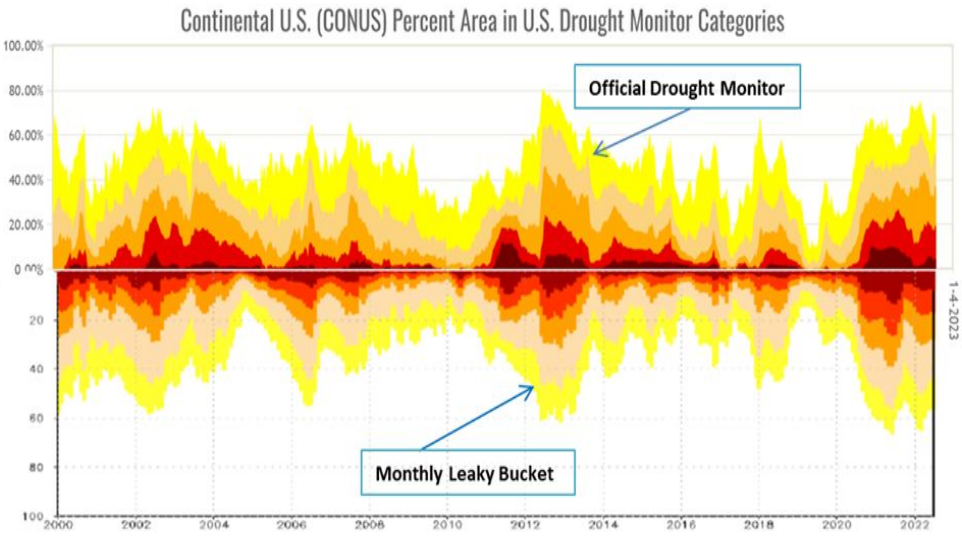


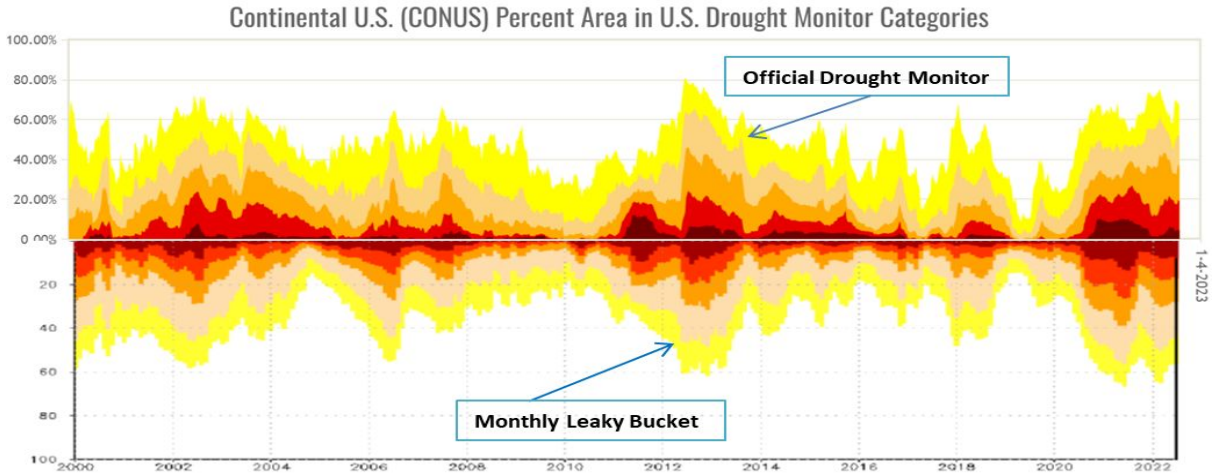
SM Application vs US Drought Monitor (USDM) -cont.

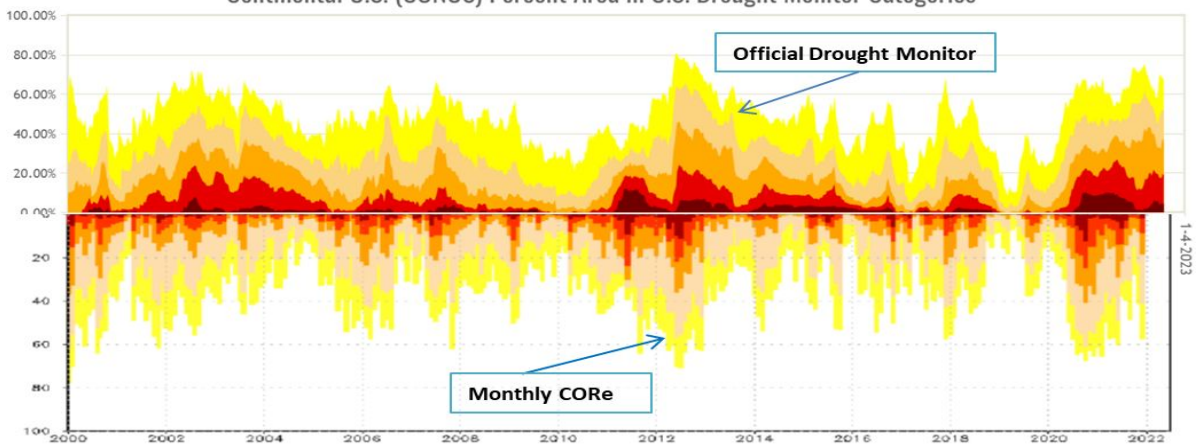


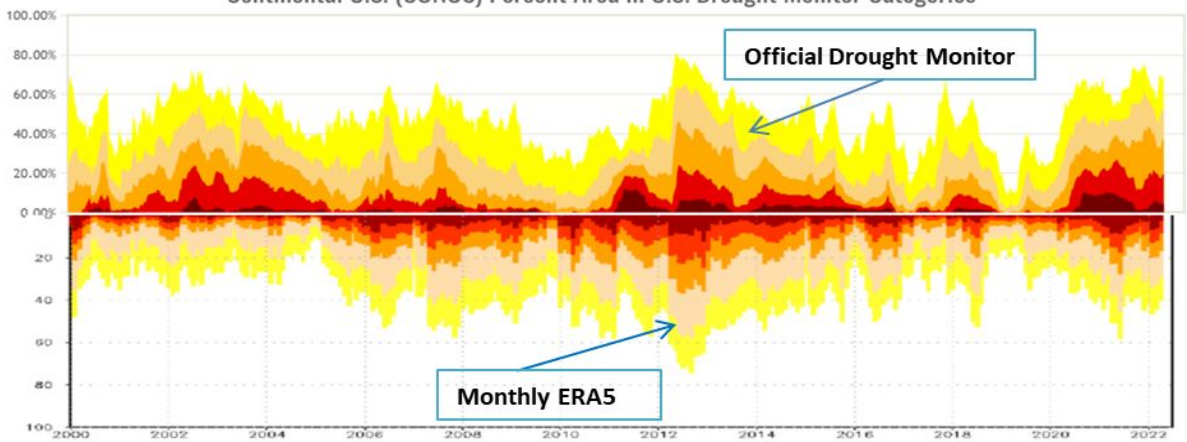

Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Daily Leaky Bucket
1-4-2023

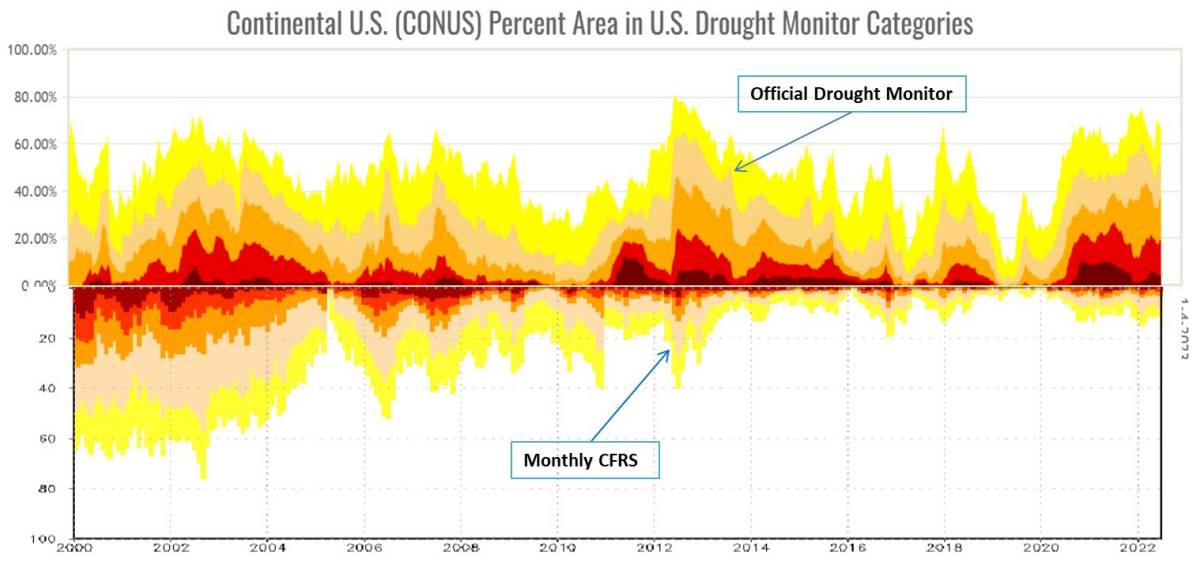

Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Monthly CD Leaky Bucket


Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Monthly Leaky Bucket
1-4-2023


Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Monthly Leaky Bucket
1-4-2023


Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Monthly CORe
1-4-2023


Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
Official Drought Monitor
Monthly ERA5


Continental U.S. (CONUS) Percent Area in U.S. Drought Monitor Categories
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
0
20
40
60
80
100
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Official Drought Monitor
Monthly CFRS

Summary

- **CORe SM has wet biases over desert regions**
- **CORe SM shows reasonable seasonal cycle in low-mid latitudes but more uncertainty in cold climate (high latitudes)**
- **CORe SM shows reasonable Interannual variations over CONUS, but some discontinuity for global domain (maybe related to Precipitation forcing). CORe SM decadal variations are too weak.**
- **SM Application vs USDM: CONUS % Area in US Drought Monitor Categories**

  match ranking: LB □ ERA5 □ CORe □ CFSR
- **CORe shows clearly improvement over CFSR**
- **As of today, modern Reanalysis still can hardly beat the offline run**