A Multi-scalar Global Assessment of Drought and Wetness Variability

Sreeparvathy Vijay[1] and Srinivas Vemavarapu[1]

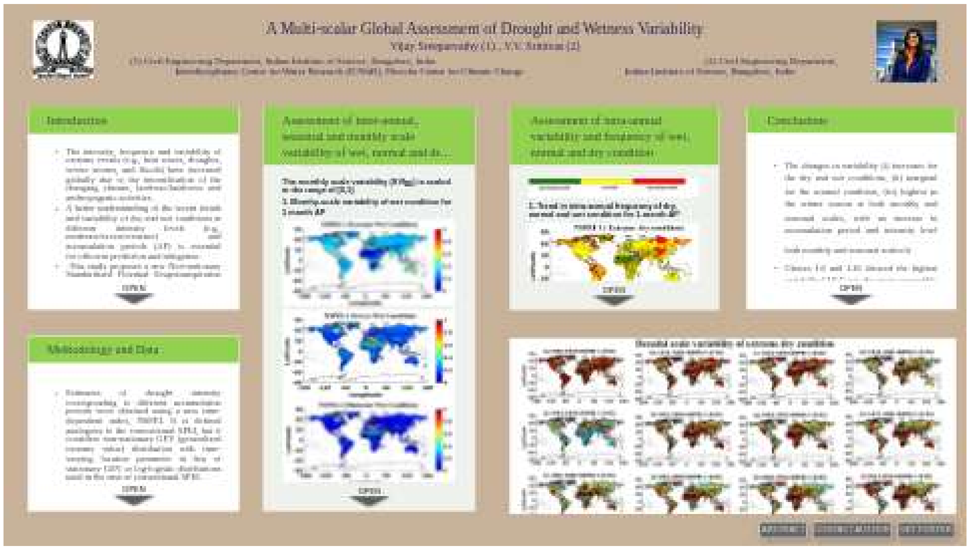
[1]Indian Institute of Science

November 23, 2022

Abstract

In recent decades, the intensity, frequency, and variability of extreme events (e.g., heat waves, droughts, severe storms, and floods) have increased globally due to the intensification of the changing climate, land-use/landcover and anthropogenic activities. An increase in extreme events results in severe economic crises and enormous disruptions in various social and environmental sectors. Hence, effective and efficient prediction and mitigation of flood and drought events are desirable. It requires a better understanding of the recent trends and variability of the extremes, which is quite challenging owing to the complex and non-stationary behaviour of the associated covariates (hydroclimatic variables, atmospheric circulation patterns), and their spatiotemporal variability and nonlinear interactions. This study proposes a new Non-stationary Standardized Potential Evapotranspiration Index (NSPEI) to assess the wetness and dryness condition and couples it with an entropy-based measure to quantify the variability of the extremes. NSPEI considers non-stationarities of both precipitation and temperature in addition to their ability to identify extreme events at different time/accumulation scales (multi-scalar). Hence, water deficits/excess could be better assessed over different accumulation periods, which helps identify and monitor various droughts (e.g., agricultural, meteorological) and water saturation conditions (e.g., floods, runoff). Furthermore, as the drought/wetness triggering variables and causes for extreme conditions may vary worldwide, a standardized drought variability index is introduced in this study to assess better drought and wetness variability across the world at multiple timescales (monthly, seasonal, annual and decadal). In addition, the influence of LULC and location indicators (latitude, longitude, and elevation) on drought and wetness variability is assessed across different continents for various time scales and severity of both wetness and dryness conditions. The analysis and outcomes of this study enhance understanding of global drought and wetness variability patterns and provide reliable information on water availability for devising effective water management strategies towards mitigation of the extremes in various continents.

A Multi-scalar Global Assessment of Drought and Wetness Variability



Vijay Sreeparvathy (1) , V.V. Srinivas (2)

(1) Civil Engineering Department, Indian Institute of Science, Bangalore, India
(2) Civil Engineering Department, Interdisciplinary Centre for Water Research (ICWaR), Divecha Centre for Climate Change Indian Institute of Science, Bangalore, India

PRESENTED AT:

INTRODUCTION

- The intensity, frequency and variability of extreme events (e.g., heat waves, droughts, severe storms, and floods) have increased globally due to the intensification of the changing climate, land-use/landcover and anthropogenic activities.
- A better understanding of the recent trends and variability of dry and wet conditions at different intensity levels (e.g., moderate/severe/extreme) and accumulation periods (AP) is essential for efficient prediction and mitigation.
- This study proposes a new Non-stationary Standardized Potential Evapotranspiration Index (NSPEI) to assess the wetness and dryness condition and couples it with an entropy-based measure to quantify the variability of the wet and dry conditions at multiple scales (decadal, annual, seasonal, and monthly).
- The variability is assesed at different accumulation periods (1, 3, 6, 12, and 24 months) to identify and monitor various droughts (e.g., agricultural, meteorological) and water saturation conditions (e.g., floods, runoff).
- In addition, the influence of LULC and location/geogrpahic indicators (latitude, longitude, and elevation) on drought and wetness variability is assessed across different continents for various time scales and severity of both wetness and dryness conditions.

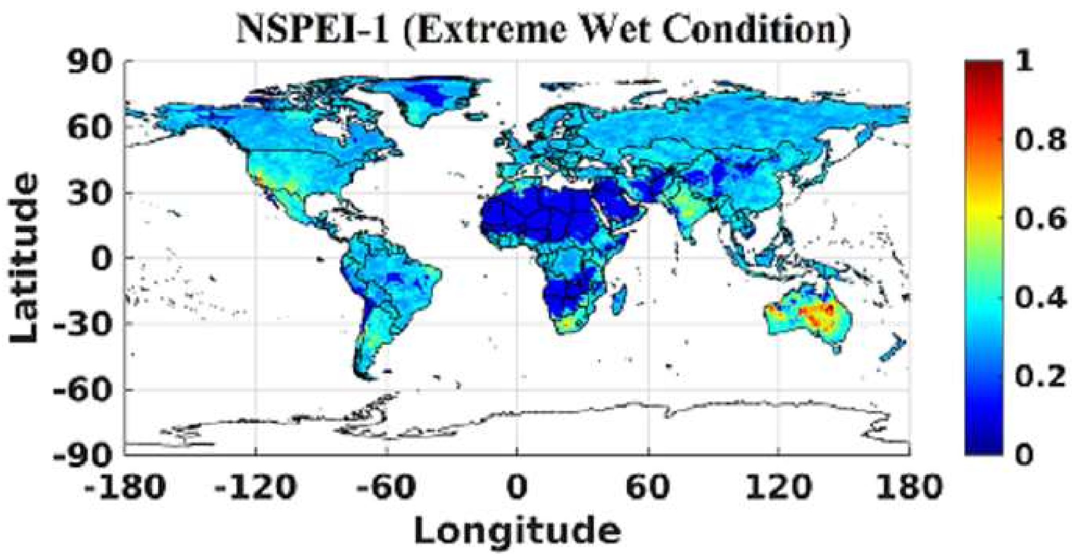
METHODOLOGY AND DATA

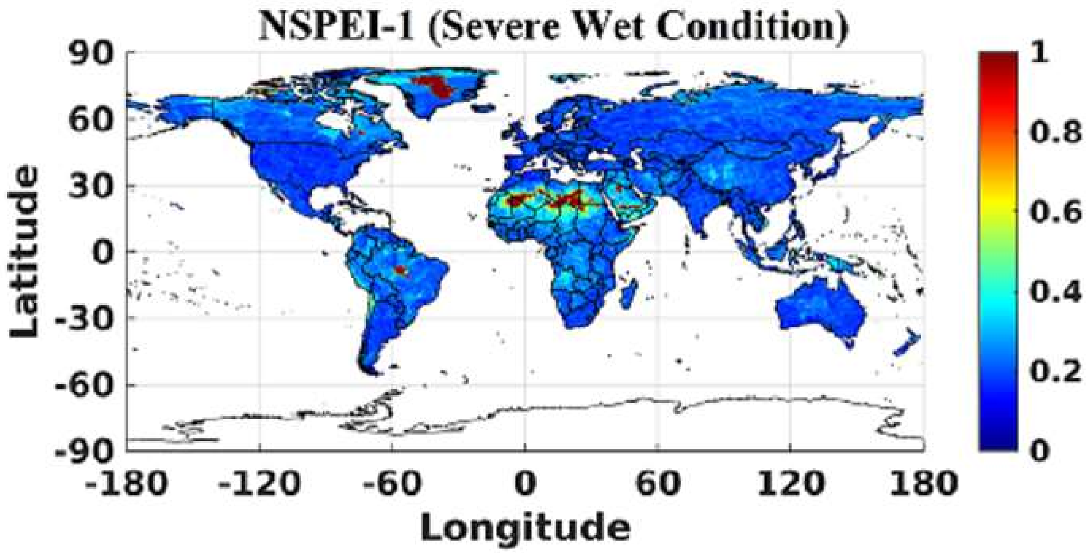
- Estimates of drought intensity corresponding to different accumulation periods were obtained using a new time-dependent index, NSPEI. It is defined analogous to the conventional SPEI, but it considers non-stationary GEV (generalized extreme value) distribution with time-varying location parameter in lieu of stationary GEV or log-logistic distributions used in the case of conventional SPEI.
- The variability of wet, normal and dry/drought conditions is quantified at different locations across the globe corresponding to different time scales and accumulation periods (1, 3, 6, 12 and 24 months) by using entropy measures (i.e., marginal entropy, ME; decadal entropy, DE; and apportionment entropy, AE). Among the measures, ME is quantified at monthly and seasonal time scales, whereas others are quantified at only monthly timescale. NSPEI corresponding to *M* months accumulation period is referred to as NSPEI-M (e.g., NSPEI-1 for 1 month).
- ME quantify the inter-annual variability (i.e., uncertainty) of the frequency (i.e., count) of wet/normal/dry months corresponding to the chosen time window/scale (yearly or seasonal).
- DE quantifies the inter-annual variability of the frequency of wet/normal/drought months in decadal time windows.
- AE quantifies the intra-annual variability of the frequency of wet/normal/drought conditions
- Standardized variability index (SVI) was considered to facilitate comparison of entropy of NSPEI estimates obtained for different sites/locations corresponding to multiple time scales, accumulation periods and intensity levels.
- NSPEI (dry/wet index) estimates were computed considering 0.5˚ resolution monthly records of precipitation and potential evapotranspiration (PET) extracted for 119 years period (1901-2019) from the climate research unit (CRU) global database.
- The LULC and elevation data of the continents were extracted from 100 m resolution Copernicus global land services Land cover (CGLS-LC) map and 30 m resolution Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM).

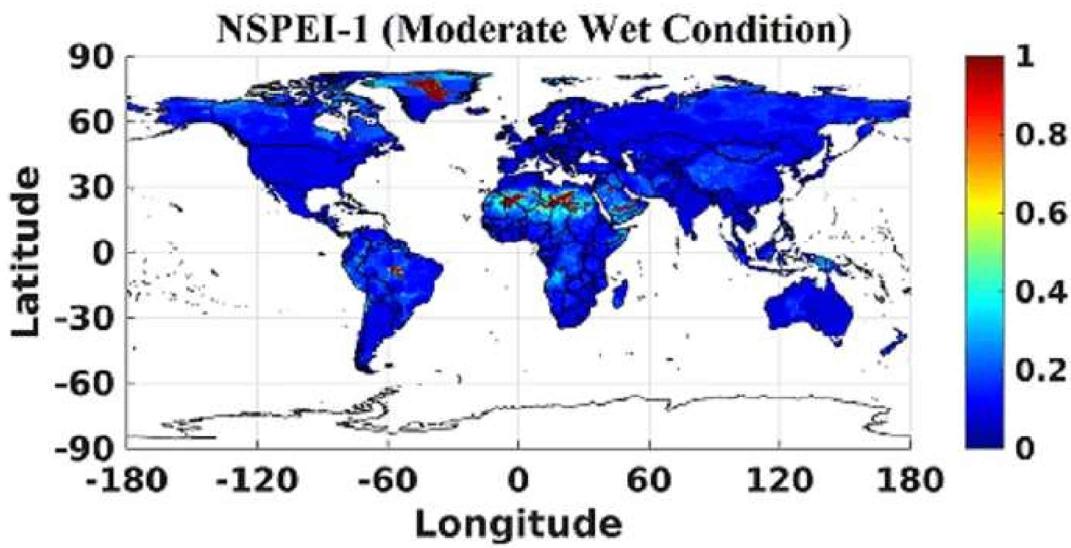
ASSESSMENT OF INTER-ANNUAL, SEASONAL AND MONTHLY SCALE VARIABILITY OF WET, NORMAL AND DRY CONDITION

The monthly scale variability (SVI_{ME}) is scaled in the range of [0,1]

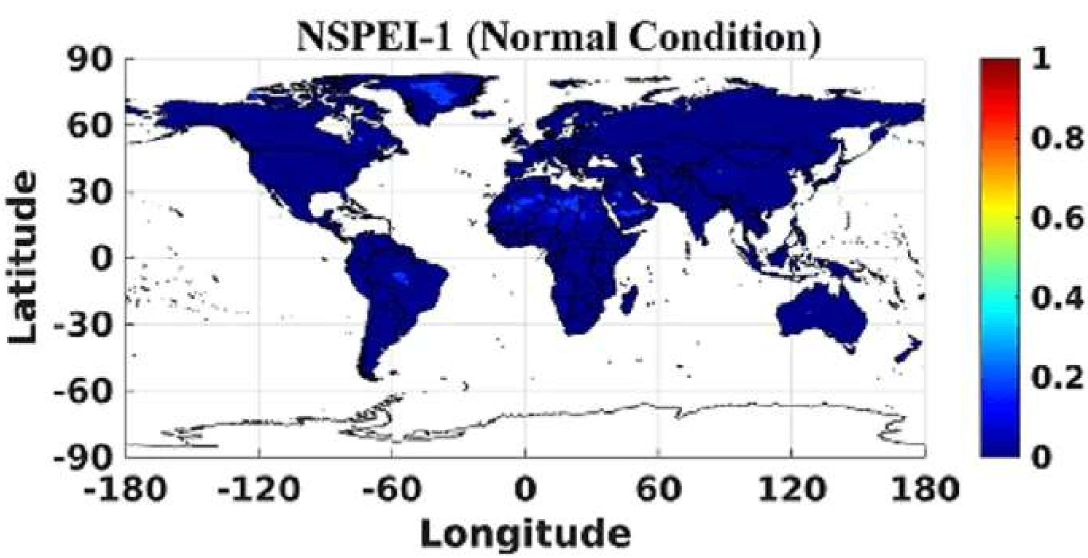
1. Monthy-scale variability of wet condition for 1 month AP



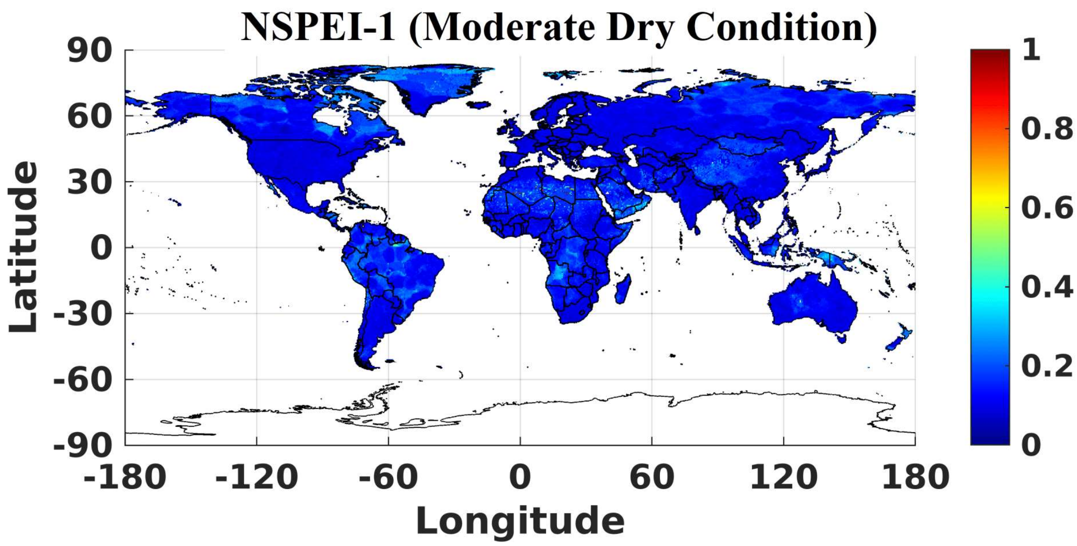


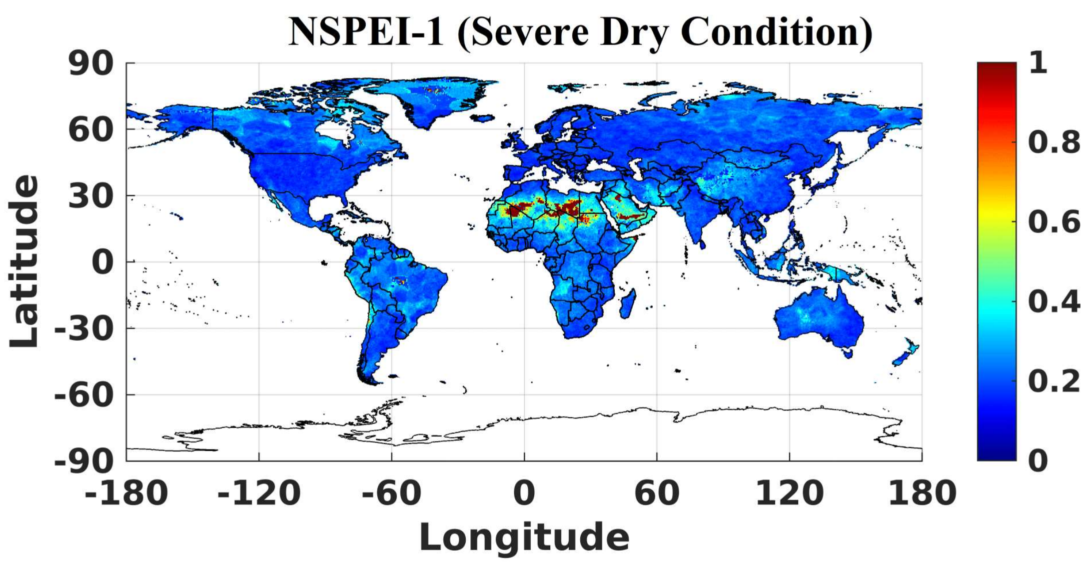


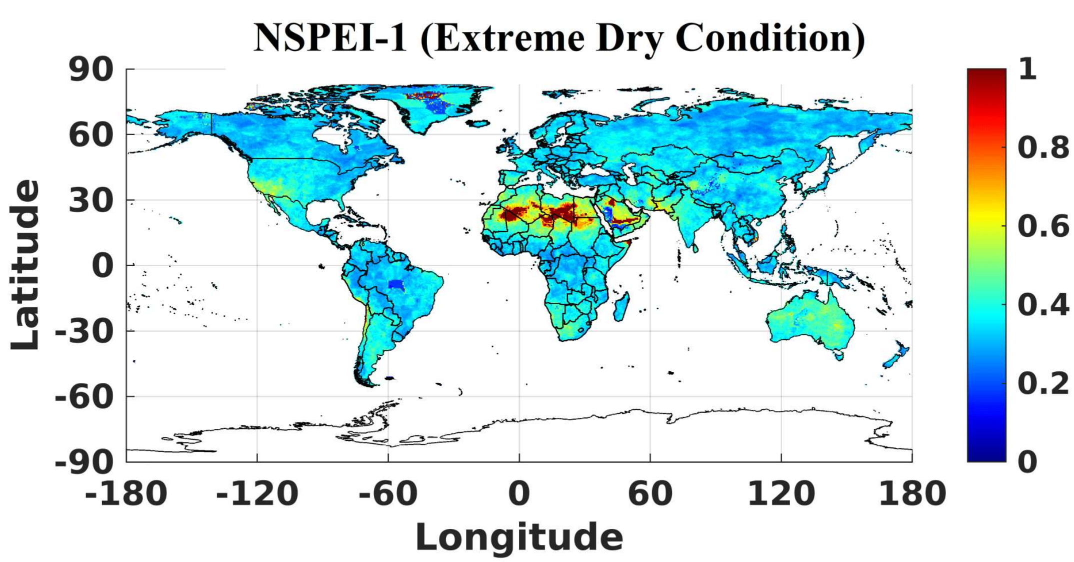
2. Monthly-scale variability of normal condition for 1 month AP



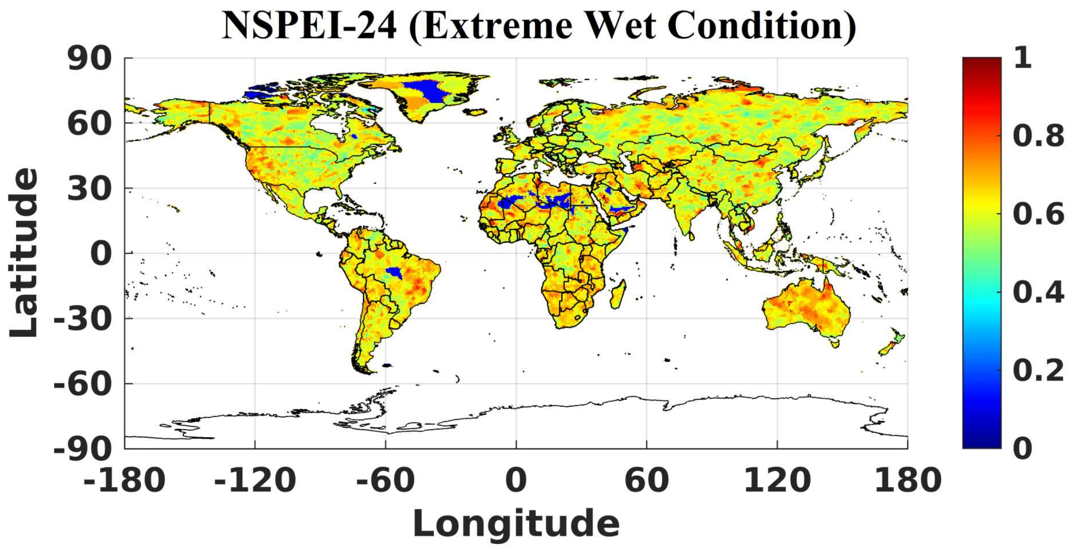
3. Monthly-scale variability of dry condition for 1 month AP

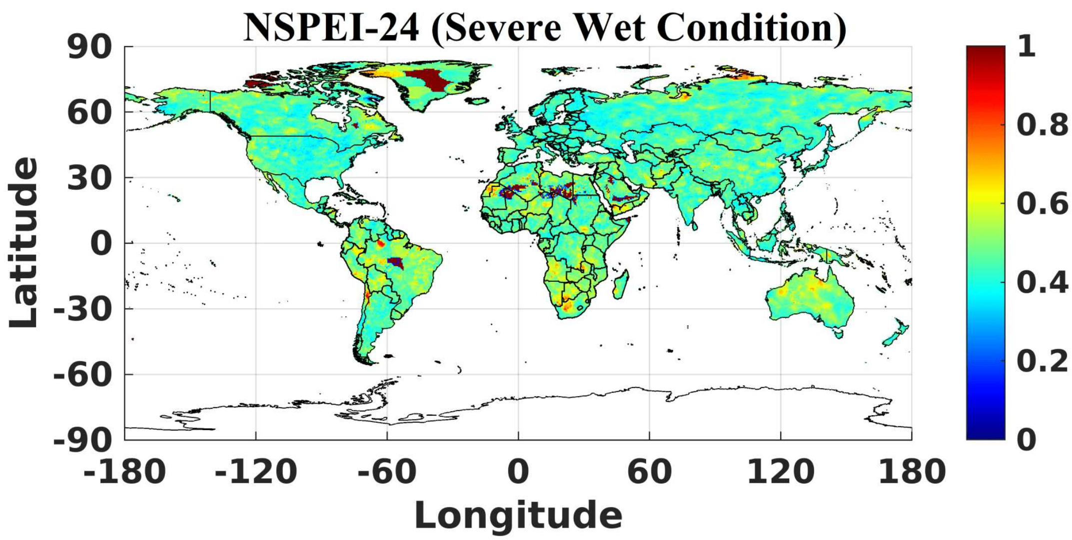


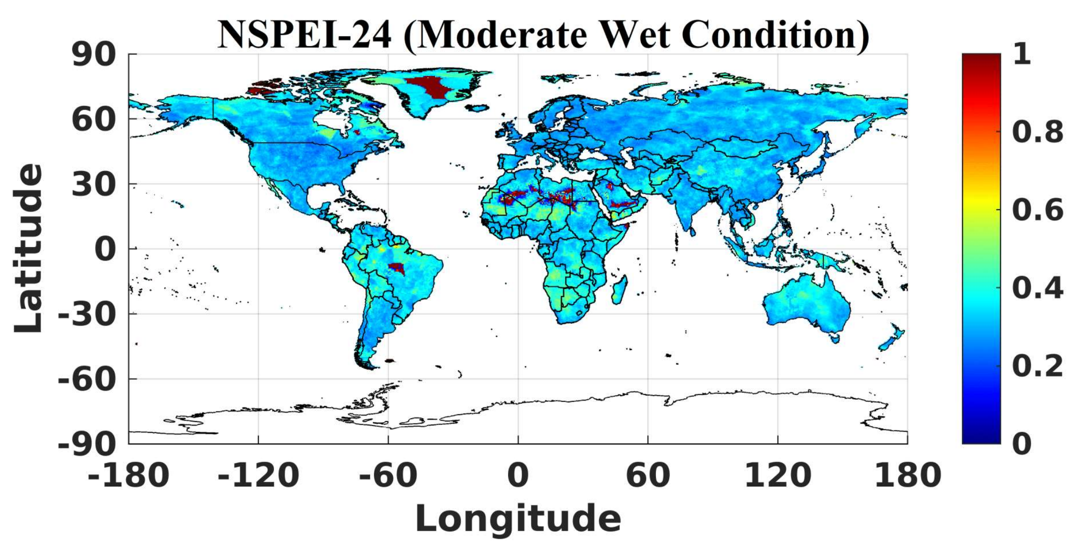




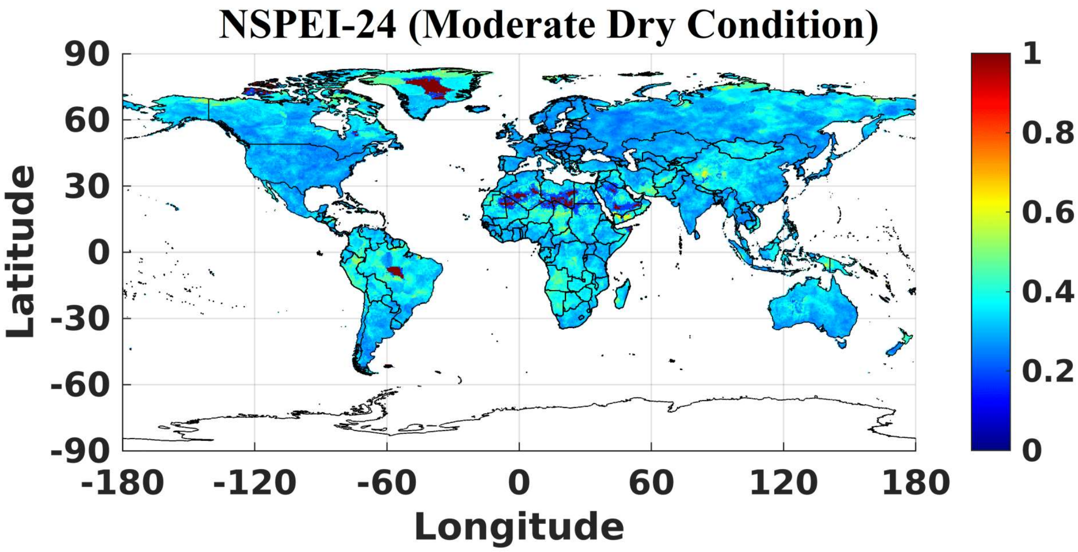
4. Monthly scale variability of wet condition for 24 months AP

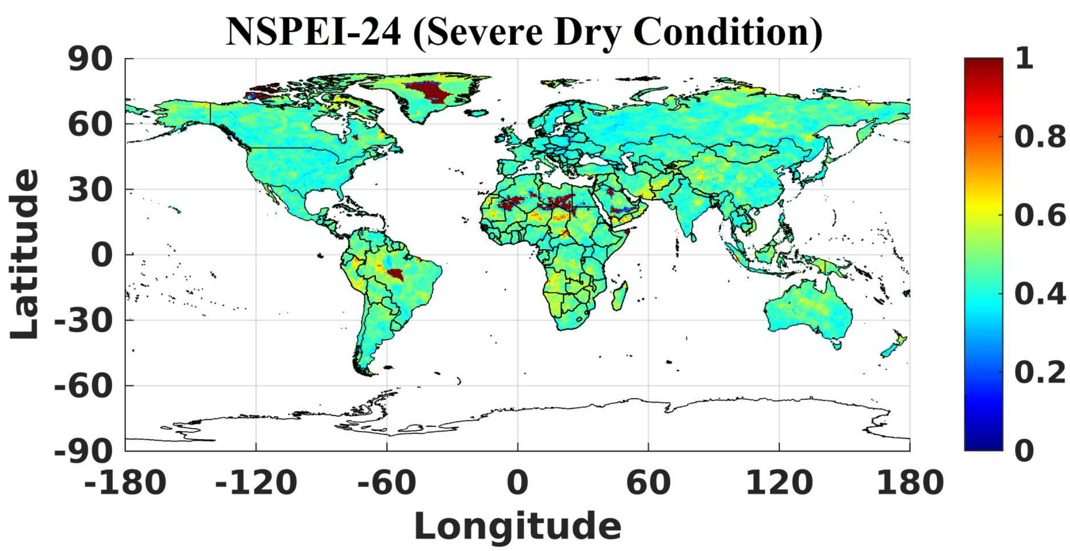

NSPEI-24 (Extreme Wet Condition)
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0

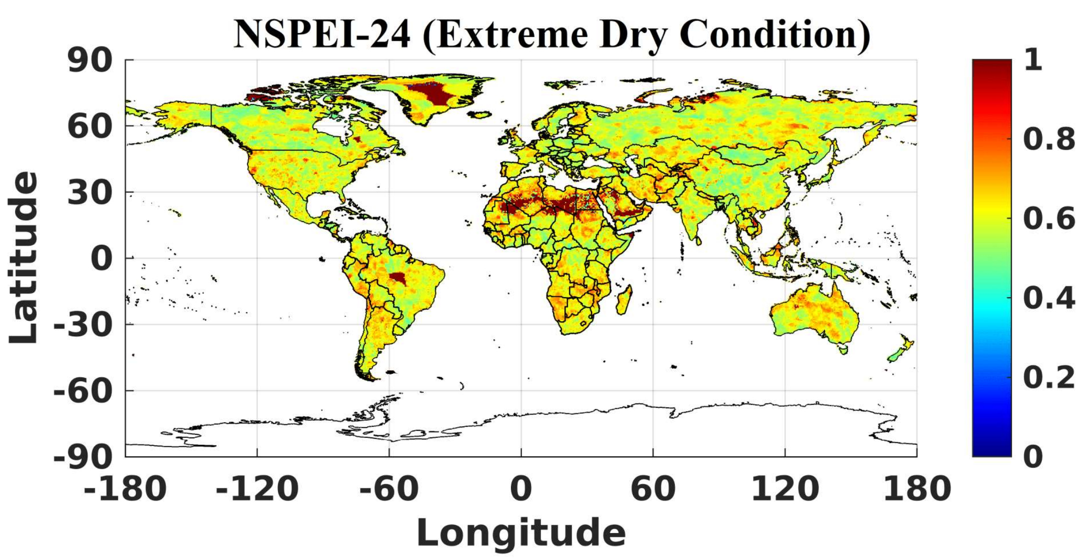

NSPEI-24 (Severe Wet Condition)
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0


NSPEI-24 (Moderate Wet Condition)
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0

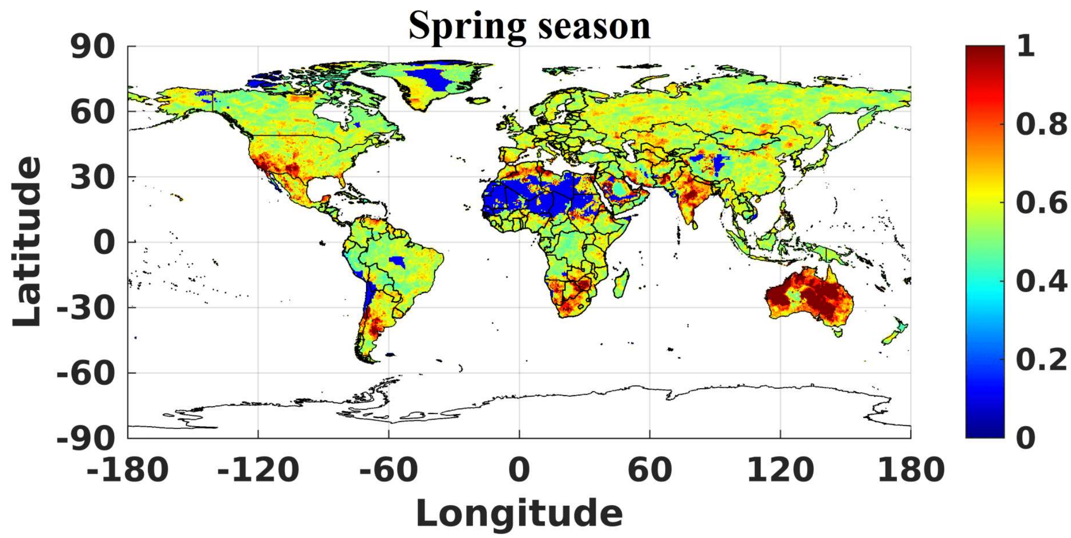
4. Monthly scale variability of dry condition for 24 months AP

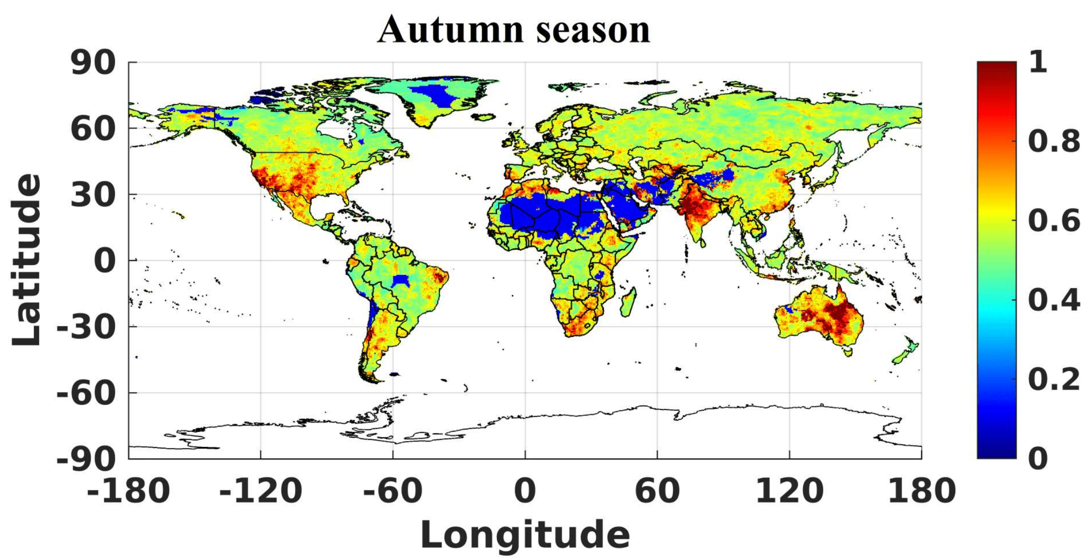


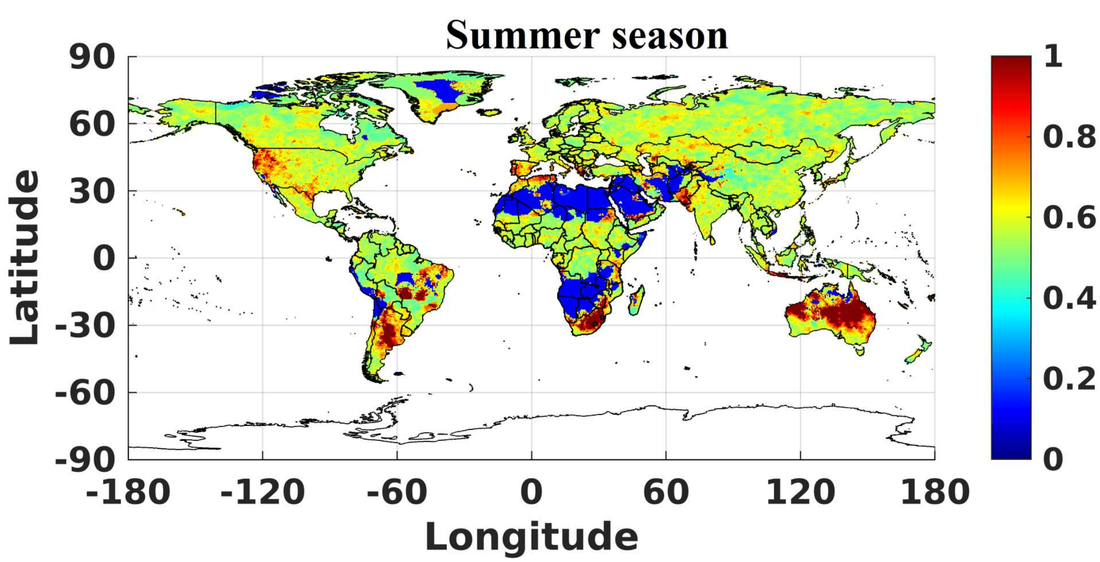


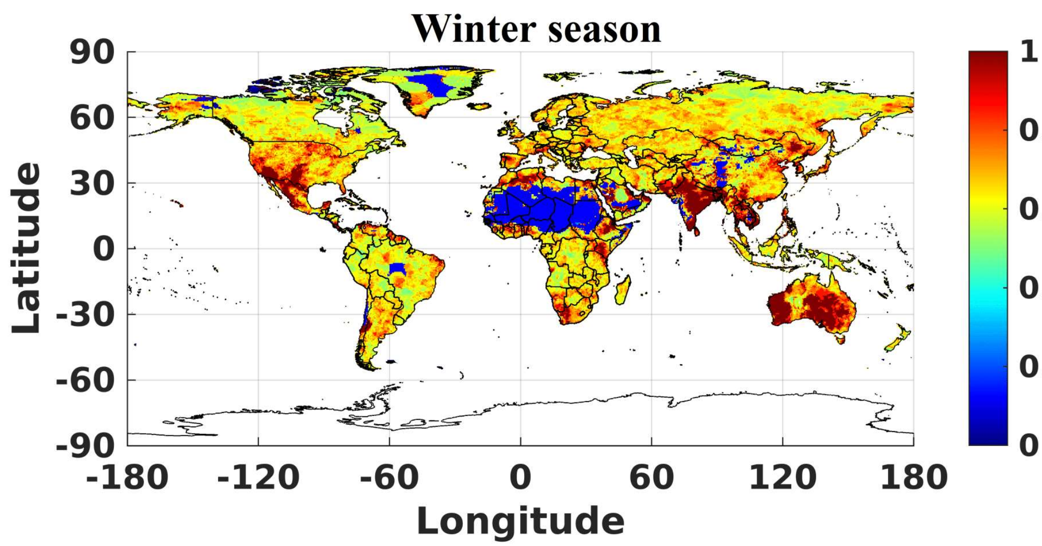


5. Seasonal scale variability of extreme wet conditon at 1-month AP

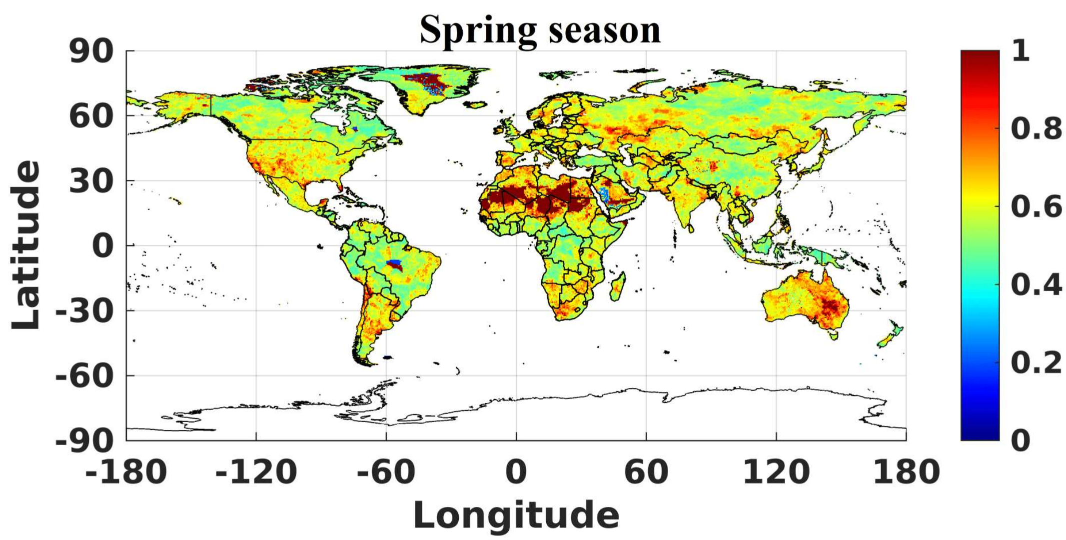

Spring season
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0

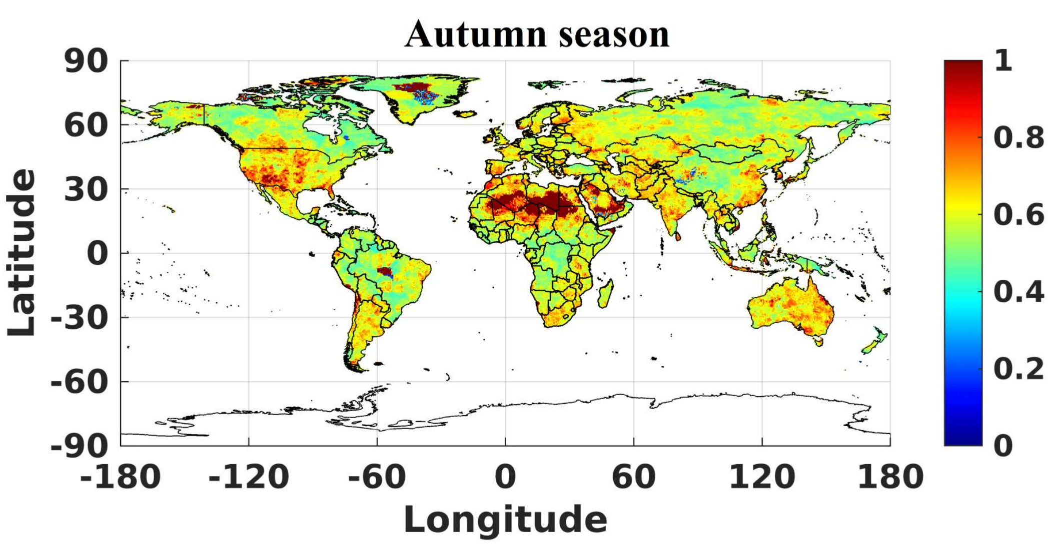

Autumn season
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0

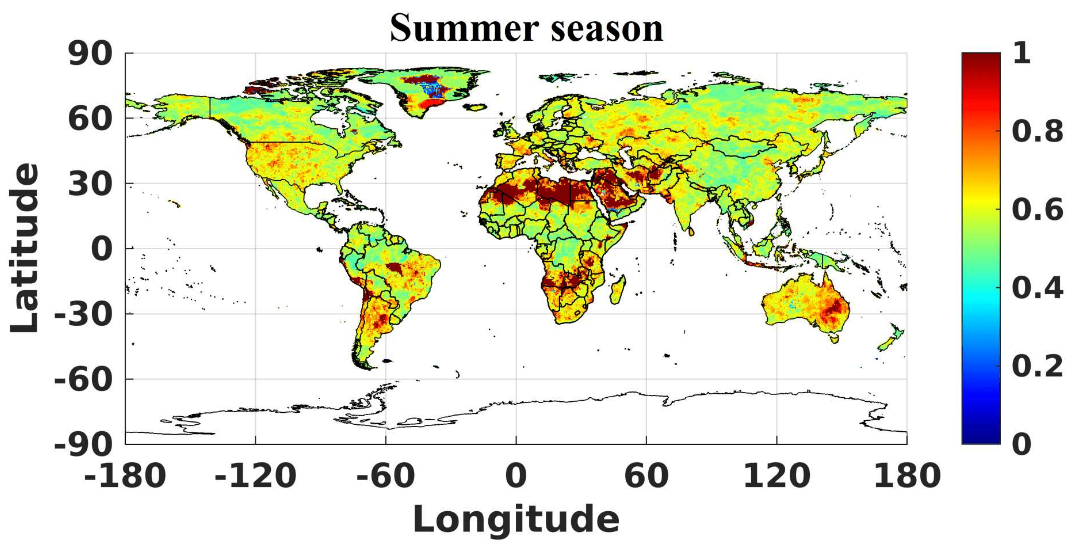

Summer season
Latitude
Longitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
1
0.8
0.6
0.4
0.2
0

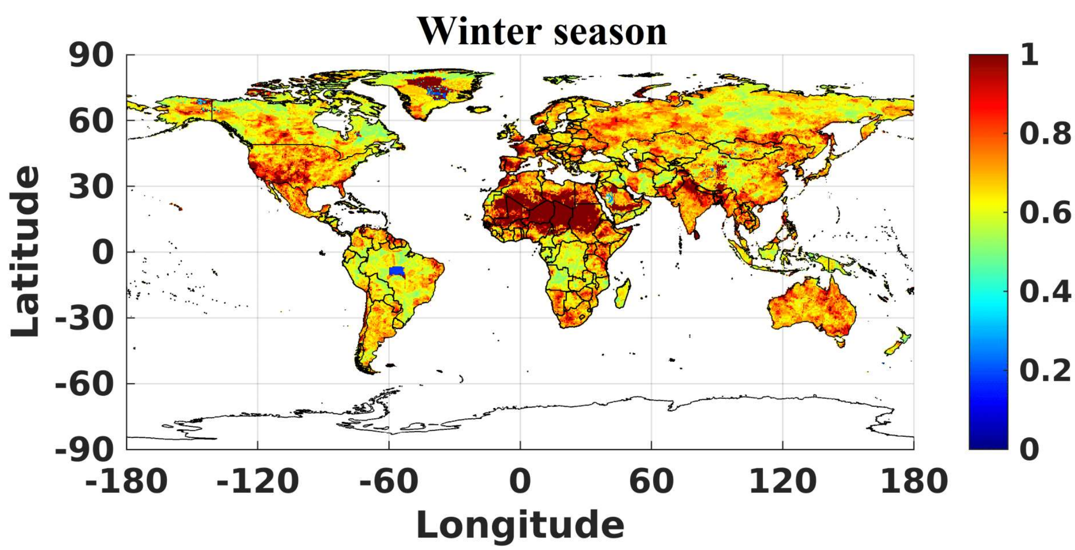


6. Seasonal scale variability of extreme dry conditon at 1-month AP

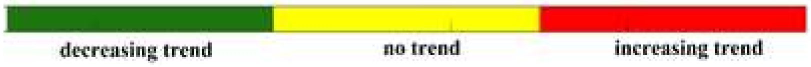




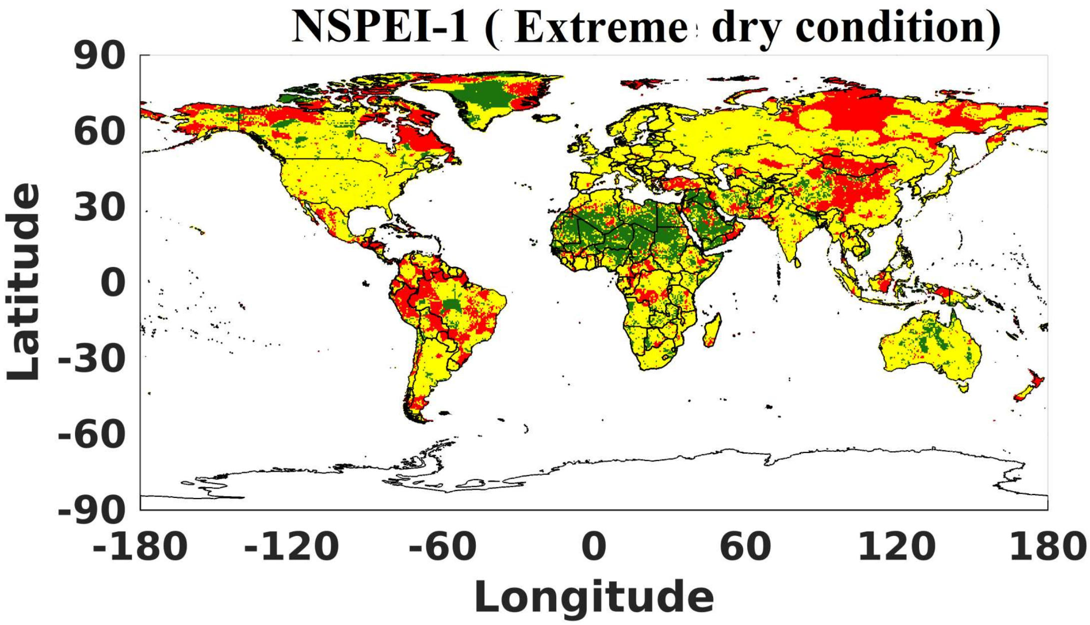

Summer season
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
1
0.8
0.6
0.4
0.2
0

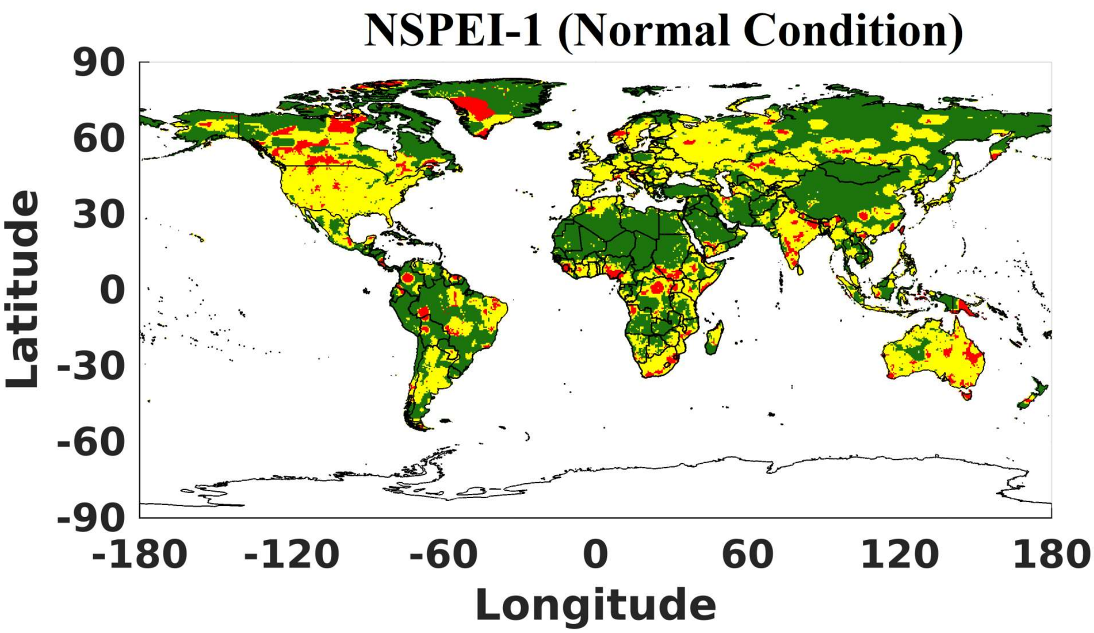

Winter season
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
1
0.8
0.6
0.4
0.2
0

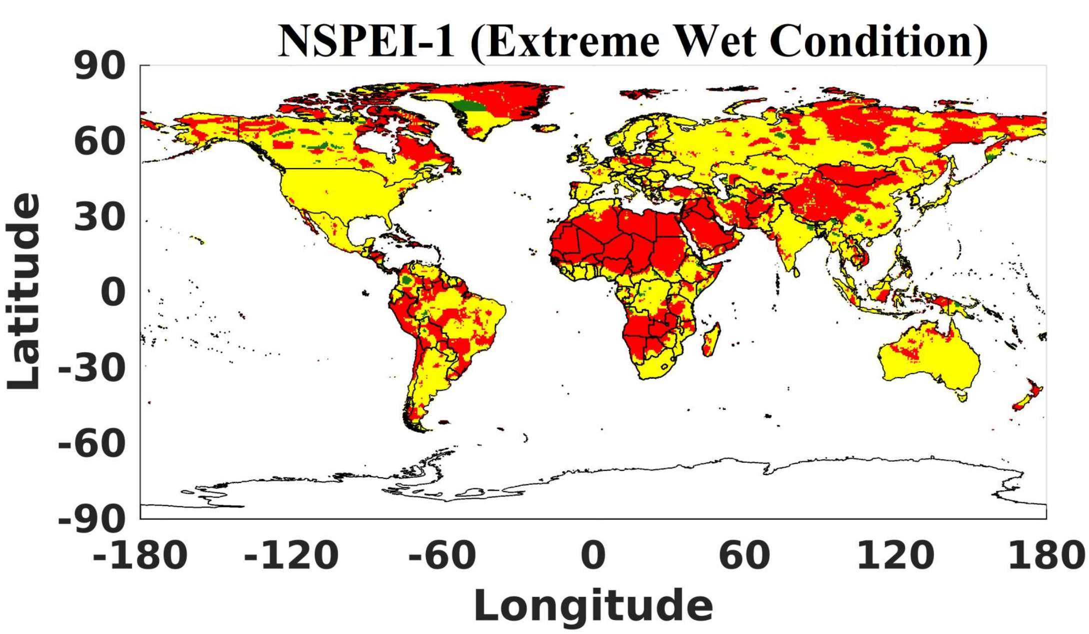
ASSESSMENT OF INTRA-ANNUAL VARIABILITY AND FREQUENCY OF WET, NORMAL AND DRY CONDITION



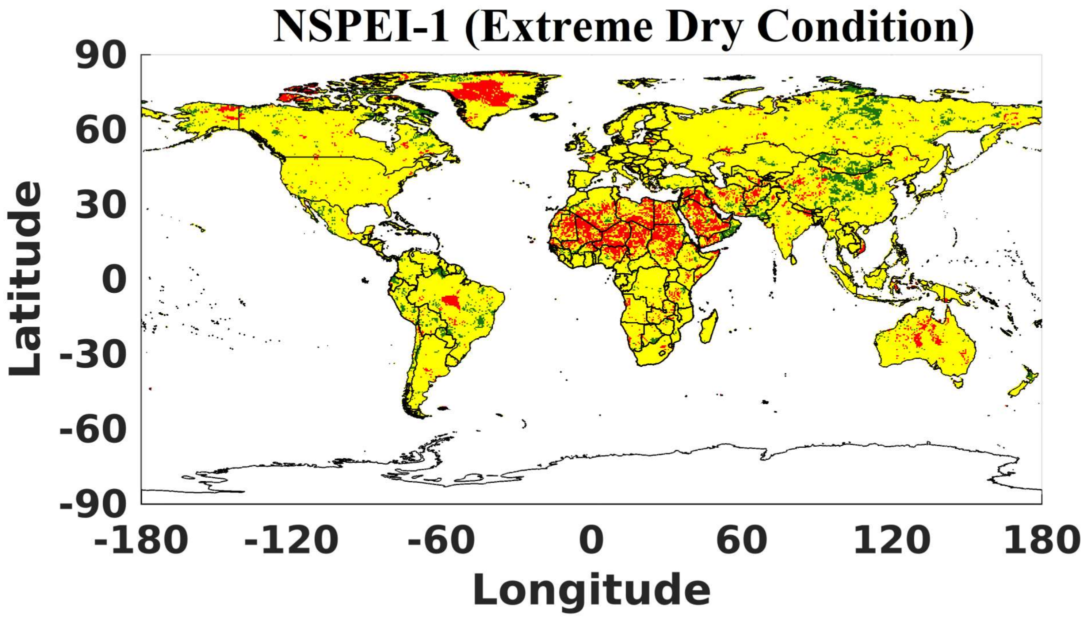
1. Trend in intra-annual frequency of dry, normal and wet condition for 1-month AP

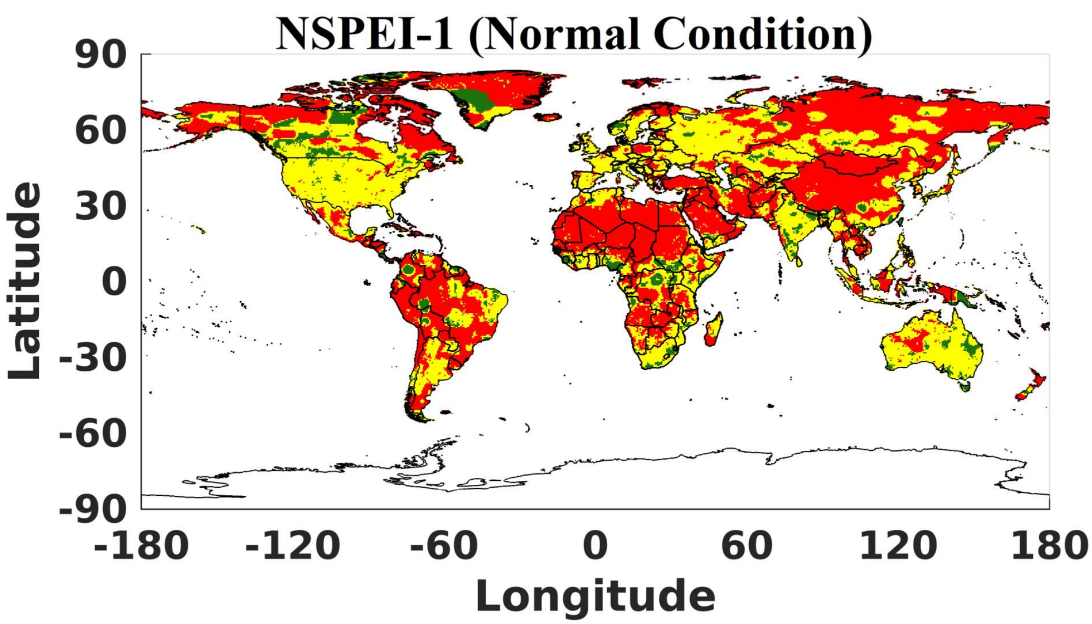

NSPEI-1 (Extreme dry condition)
Latitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
Longitude

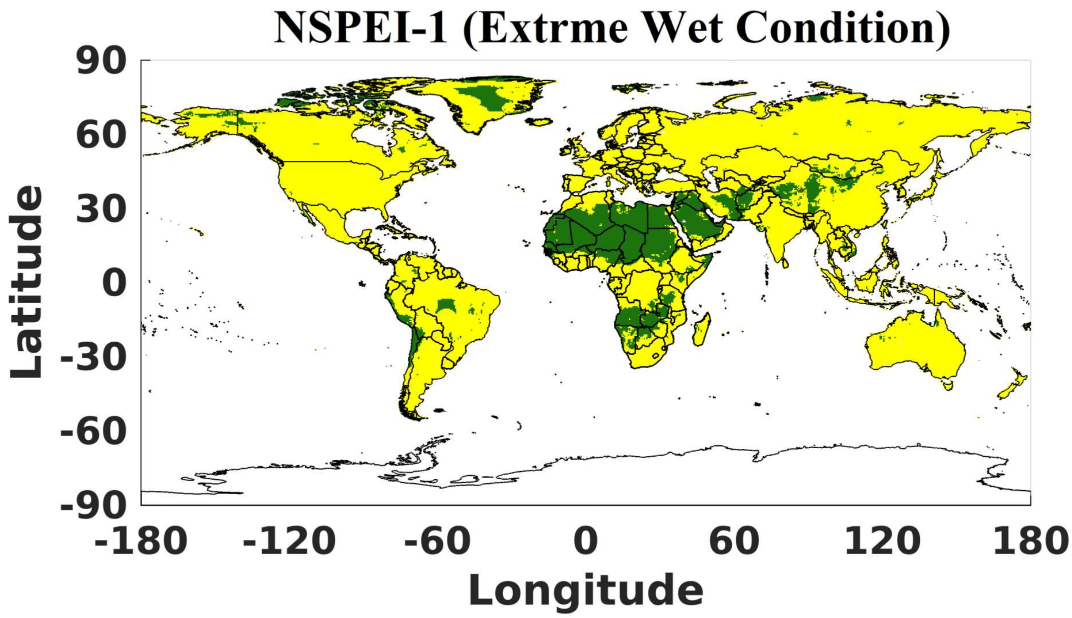

NSPEI-1 (Normal Condition)
Latitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
Longitude


NSPEI-1 (Extreme Wet Condition)
Latitude
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
Longitude

2. Trend in intra-annual variability of dry, normal and wet condition for 1-month AP

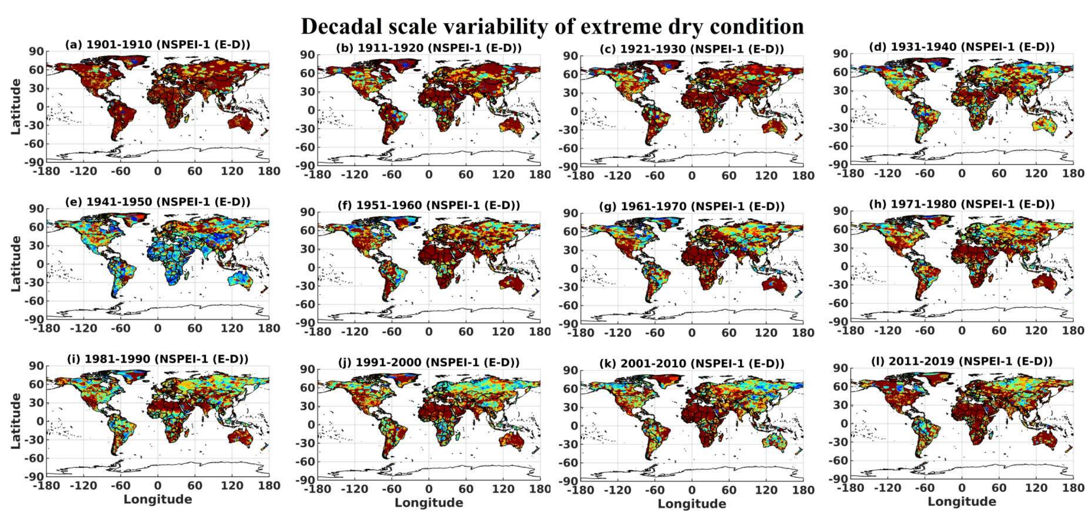




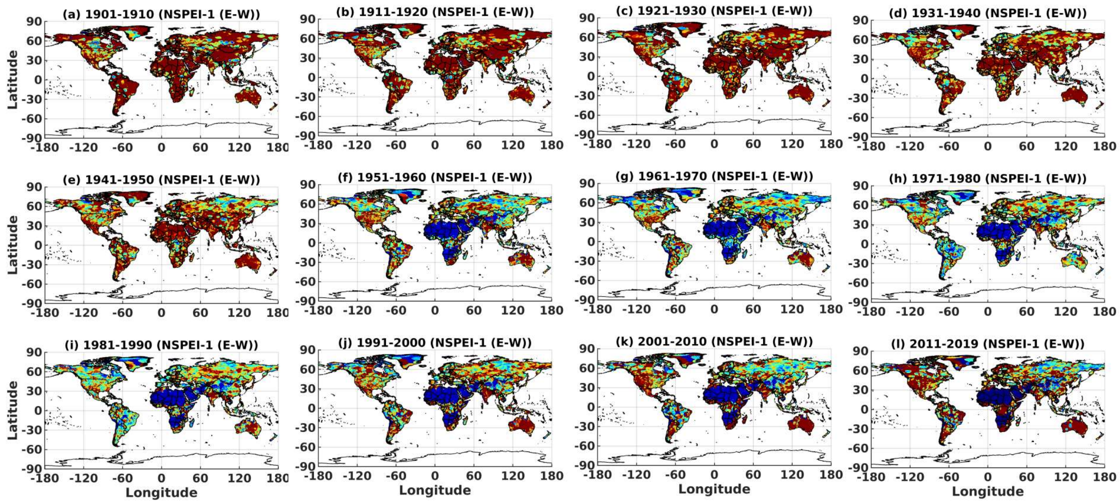

NSPEI-1 (Extrme Wet Condition)
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude

CONCLUSIONS

- The changes in variability (i) increases for the dry and wet conditions, (ii) marginal for the normal condition, (iii) highest in the winter season~~ at both monthly and seasonal scales~~, with an increase in accumulation period and intensity level both monthly and seasonal scalesAt
- Classes L6 and L10 showed the highest variability.~~LULC ~~are the most susceptible for variability in wet and dry conditions and among those classes L5 (Herbaceous wetlands), L6 (Moss and lichen), L7 (bare vegetation) and L10 (snow and ice) ~~classes LULC ~~revealed that, globally, the ~~variability on ~~esLULC class~~influence of ~~different variability associated with Analysis on the
- Changes in variability with elevation showed that, among different continents, North America, Europe, and Australia showed a decrease in variability of dry/wet conditions with an increase in elevation, and maximum variability occurs for lower elevation ranges (mainly 0-1000 m).~~ the~~ analysis onThe
- Trend analysis on the frequency/count of dry and wet conditions indicated that wet and dry months are increasing in various parts of the world.
- A majority of the locations showed a decreasing trend in the frequency and an increasing trend in variability for normal conditions. This clearly indicates that the effect of climate change is real and found to have a profound effect on the frequency and variability of extreme events (i.e., dry/wet spells).
- Analysis on the decadal-scale variability of wet/normal/dry conditions indicated a noticeable decrease in variability of wet conditions from the 1950s and dry condition from the 1930s.



Decadal scale variability of extreme wet condition



ABSTRACT

In recent decades, the intensity, frequency, and variability of extreme events (e.g., heat waves, droughts, severe storms, and floods) have increased globally due to the intensification of the changing climate, land-use/landcover and anthropogenic activities. An increase in extreme events results in severe economic crises and enormous disruptions in various social and environmental sectors. Hence, effective and efficient prediction and mitigation of flood and drought events are desirable. It requires a better understanding of the recent trends and variability of the extremes, which is quite challenging owing to the complex and non-stationary behaviour of the associated covariates (hydroclimatic variables, atmospheric circulation patterns), and their spatiotemporal variability and nonlinear interactions. This study proposes a new Non-stationary Standardized Potential Evapotranspiration Index (NSPEI) to assess the wetness and dryness condition and couples it with an entropy-based measure to quantify the variability of the extremes. NSPEI considers non-stationarities of both precipitation and temperature in addition to their ability to identify extreme events at different time/accumulation scales (multi-scalar). Hence, water deficits/excess could be better assessed over different accumulation periods, which helps identify and monitor various droughts (e.g., agricultural, meteorological) and water saturation conditions (e.g., floods, runoff). Furthermore, as the drought/wetness triggering variables and causes for extreme conditions may vary worldwide, a standardized drought variability index is introduced in this study to assess better drought and wetness variability across the world at multiple timescales (monthly, seasonal, annual and decadal). In addition, the influence of LULC and location indicators (latitude, longitude, and elevation) on drought and wetness variability is assessed across different continents for various time scales and severity of both wetness and dryness conditions. The analysis and outcomes of this study enhance understanding of global drought and wetness variability patterns and provide reliable information on water availability for devising effective water management strategies towards mitigation of the extremes in various continents.