DROUGHT HAZARDS 1: METEOROLOGICAL DROUGHTS

Overview of different indicators and tools for characterizing, assessing and monitoring meteorological droughts

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DROUGHTS

- 11 million people died of drought, 2 billion affected since 1900

- Global impacts on agriculture, society and economic losses

- Increasing frequency of drought events

- **Meteorological**, agricultural, hydrological and socio-economic droughts

(FAO, 2013)

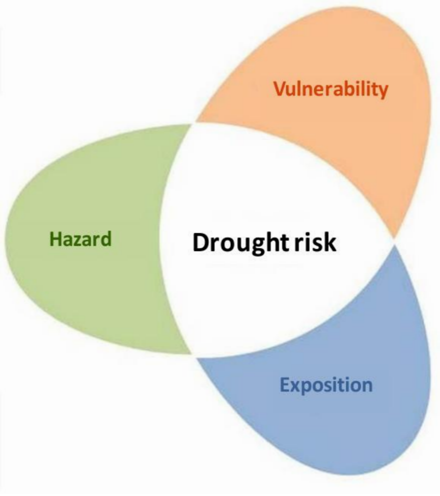
GLOBE DROUGHT

- Web-based drought information system
- Drought monitor
- Considering drought risk and impact
    - Hazard
    - Exposure
    - Vulnerability

- Different remote sensing data products and models for analysing the drought types

- historical, NRT and early warning component

- 1st webinar and lecture



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GLOBE DROUGHT

Globe Drought GRoW GLOBALE RESSOURCE WASSER SPONSORED BY THE Federal Ministry of Education and Research

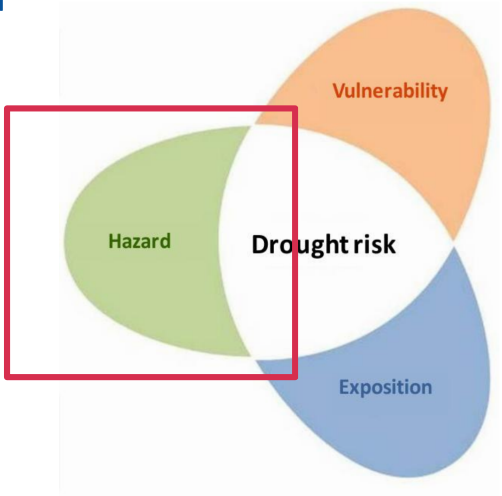
IGG in GlobeDrought

- Drought hazard

- Hazard indicators for meteorological and GRACE-based indicators for hydrological drought

- Different indicators are merged to a combined hazard indicator

- Global and regional analysis

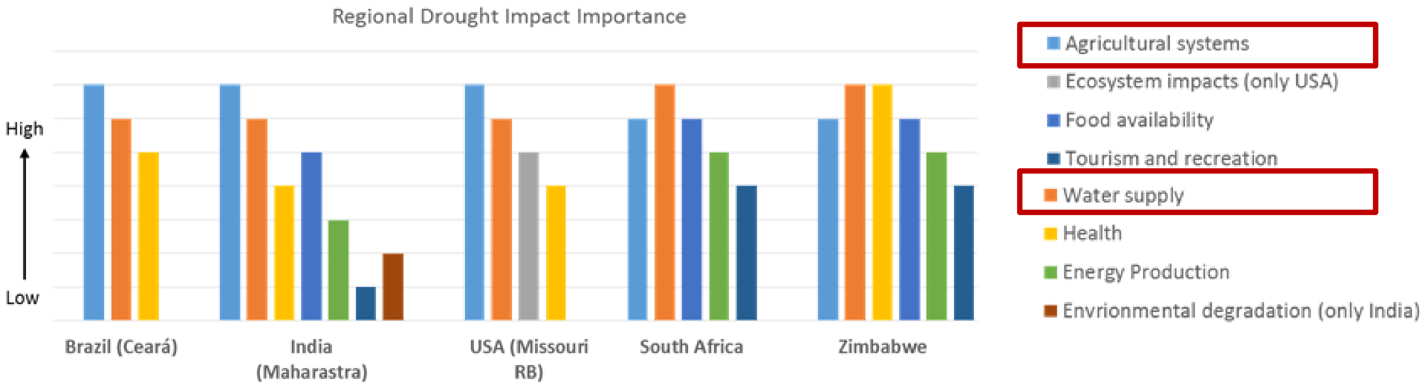


DROUGHT IMPACTS

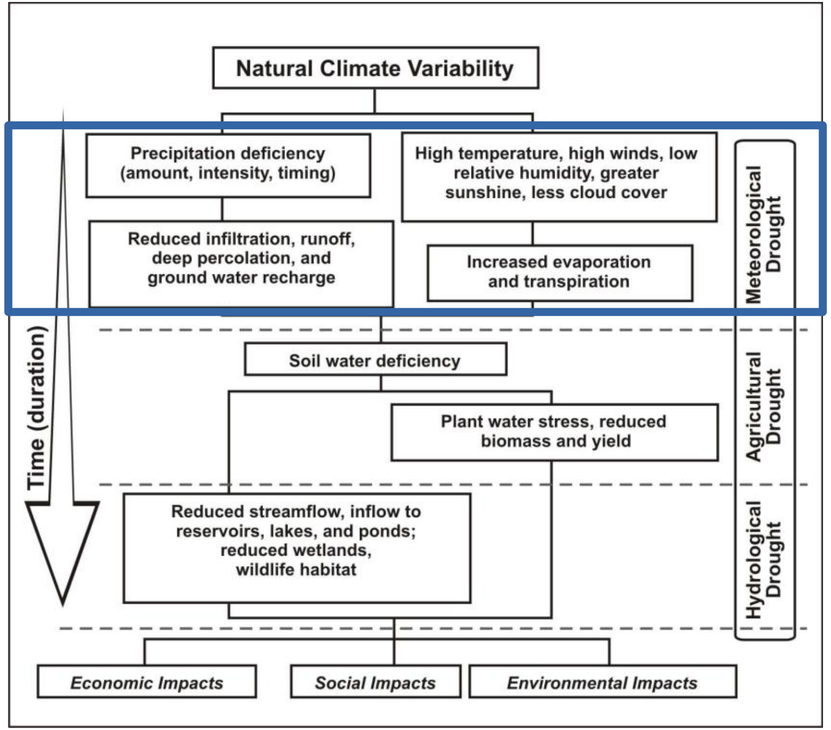
Rainfed agricultural systems

Irrigated agricultural systems

Water supply



BACKGROUND



National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A

Meteorological drought

- Mainly precipitation deficit
- precipitation is flux
- eLecture

Agricultural drought

- Soil moisture deficit

Hydrological drought

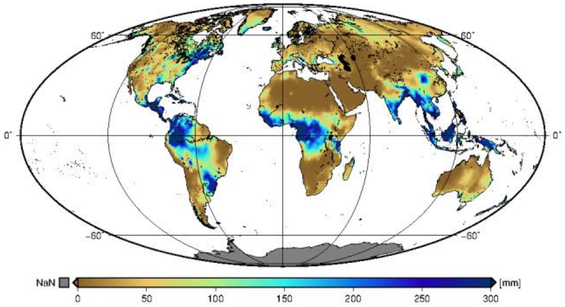
- Effect of precipitation shortfalls on surface/subsurface water storages
- Phase shift to meteorological droughts

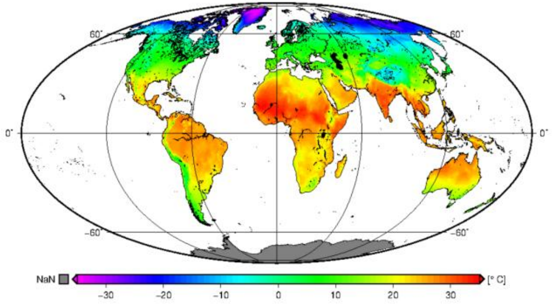
→ Drought hazard

WFD/WFDEI DATA SET

PRECIPITATION, TEMPERATURE

- WFD/WFDEI dataset, Weedon et al. (2010, 2011, 2014)
- Homogenized and provided by University Frankfurt, Müller Schmied et al. (2016)
- Homogenization to bias correct offset between climate variables of WFD and WFDEI



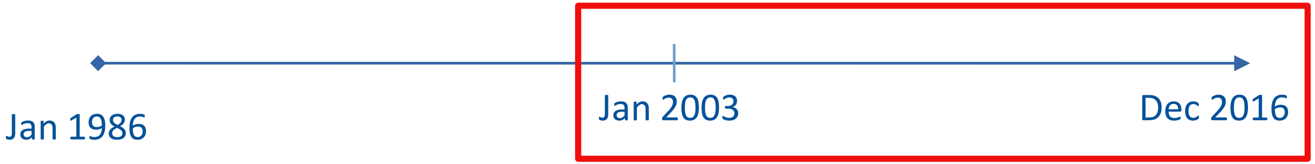


WFD/WFDEI DATA SET

GENERAL FACTS

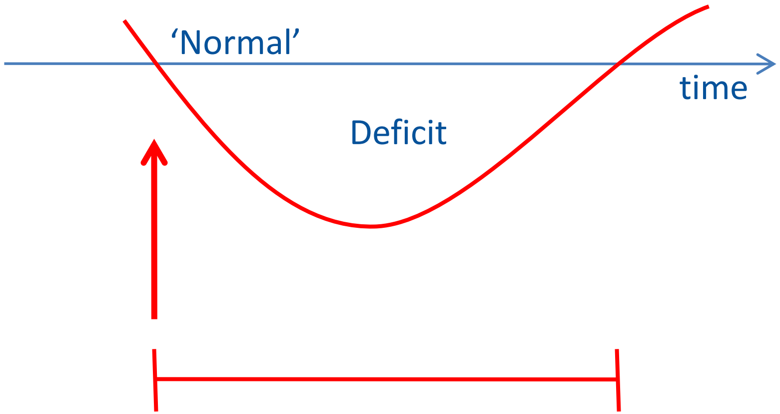
- Period: computation for 1986 to 2016, results 2003-2016
- Temporal resolution: daily, transformed to monthly
- Spatial resolution: 0.5 x 0.5° grid

Study area: global and regional: South Africa, Maharashtra (West India), Ceará (East Brazil), Missouri river basin (US), Zimbabwe



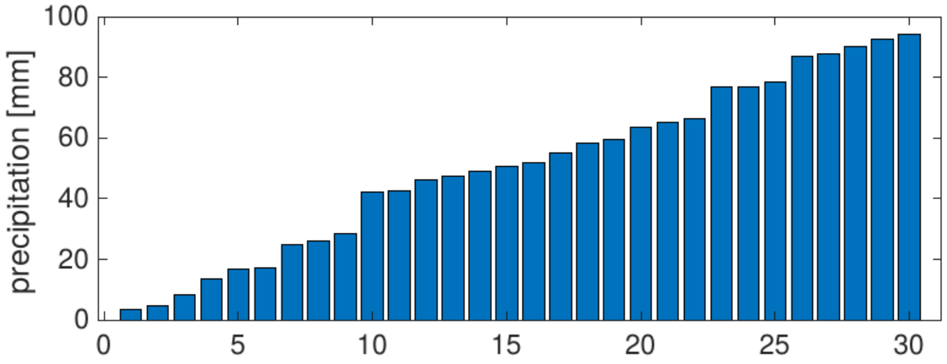
DROUGHT INDICATORS

- Characterization (retroperspective), monitoring and triggering management plans and decisions for drought
- Defined to the ‘normal’ condition
- Often based on threshold, percentiles, standardization, etc.
- Describing the drought events by:
    - Location
    - Timing
    - Duration
    - Severity



DROUGHT INDICATORS

- Precipitation for one month of each year e.g. January
- Compare to ‘normal’ condition
  - Percentiles
  - Probability distribution
  - Standardization, Normalization



DROUGHT INDICATORS

Meteorology	Page	Ease of use	Input parameters	Additional information
Aridity Anomaly Index (AAI)	11	Green	P, T, PET, ET	Operationally available for India
Deciles	11	Green	P	Easy to calculate; examples from Australia are useful
Keetch–Byram Drought Index (KBDI)	12	Green	P, T	Calculations are based upon the climate of the area of interest
Percent of Normal Precipitation	12	Green	P	Simple calculations
Standardized Precipitation Index (SPI)	13	Green	P	Highlighted by the World Meteorological Organization as a starting point for meteorological drought monitoring
Weighted Anomaly Standardized Precipitation (WASP)	15	Green	P, T	Uses gridded data for monitoring drought in tropical regions
Aridity Index (AI)	15	Yellow	P, T	Can also be used in climate classifications
China Z Index (CZI)	16	Yellow	P	Intended to improve upon SPI data
Crop Moisture Index (CMI)	16	Yellow	P, T	Weekly values are required
Drought Area Index (DAI)	17	Yellow	P	Gives an indication of monsoon season performance
Drought Reconnaissance Index (DRI)	17	Yellow	P, T	Monthly temperature and precipitation are required
Effective Drought Index (EDI)	18	Yellow	P	Program available through direct contact with originator
Hydro-thermal Coefficient of Selyaninov (HTC)	19	Yellow	P, T	Easy calculations and several examples in the Russian Federation
NOAA Drought Index (NDI)	19	Yellow	P	Best used in agricultural applications
Palmer Drought Severity Index (PDSI)	20	Yellow	P, T, AWC	Not green due to complexity of calculations and the need for serially complete data
Palmer Z Index	20	Yellow	P, T, AWC	One of the many outputs of PDSI calculations
Rainfall Anomaly Index (RAI)	21	Yellow	P	Serially complete data required
Self-Calibrated Palmer Drought Severity Index (sc-PDSI)	22	Yellow	P, T, AWC	Not green due to complexity of calculations and serially complete data required
Standardized Anomaly Index (SAI)	22	Yellow	P	Point data used to describe regional conditions
Standardized Precipitation Evapotranspiration Index (SPEI)	23	Yellow	P, T	Serially complete data required; output similar to SPI but with a temperature component
Agricultural Reference Index for Drought (ARID)	23	Red	P, T, Mod	Produced in south-eastern United States of America and not tested widely outside the region
Crop-specific Drought Index (CSDI)	24	Red	P, T, Td, W, Rad, AWC, Mod, CD	Quality data of many variables needed, making it challenging to use
Reclamation Drought Index (RDI)	25	Red	P, T, S, RD, SF	Similar to the Surface Water Supply Index, but contains a temperature component

Reference: Svoboda and Fuchs, 2016

IMPLEMENTATION

FOUR DIFFERENT METEOROLOGICAL DROUGHT INDICATORS

- Standardized Precipitation Index (SPI) → P
- Standardized Precipitation Evapotranspiration Index (SPEI)→ P,T
  - Accumulation periods and distribution functions
- Weighted Anomaly Standardized Precipitation Index (WASP)
  - Accumulation periods, standardization and weighting
- Percentile Index
  - Percentile rank method

LITERATURE RESEARCH

	Pros	Cons
SPI	All climate regions Multiple time scales Can handle gaps	No temperature Should be based on long data record
SPEI	All climate regions Multiple time scales Can handle gaps Temperature	Should be based on long data record
WASP	Weighting reduces artificially magnified precipitation (start and end of year)	Worse results in desert
Percentiles	Less complex	Requires long data record

Found in Arnold (2006), Svoboda and Fuchs (2016) and Schär et al. (2016)

GLOBAL ANALYSIS

IMPLEMENTATION

FOUR DIFFERENT METEOROLOGICAL DROUGHT INDICATORS

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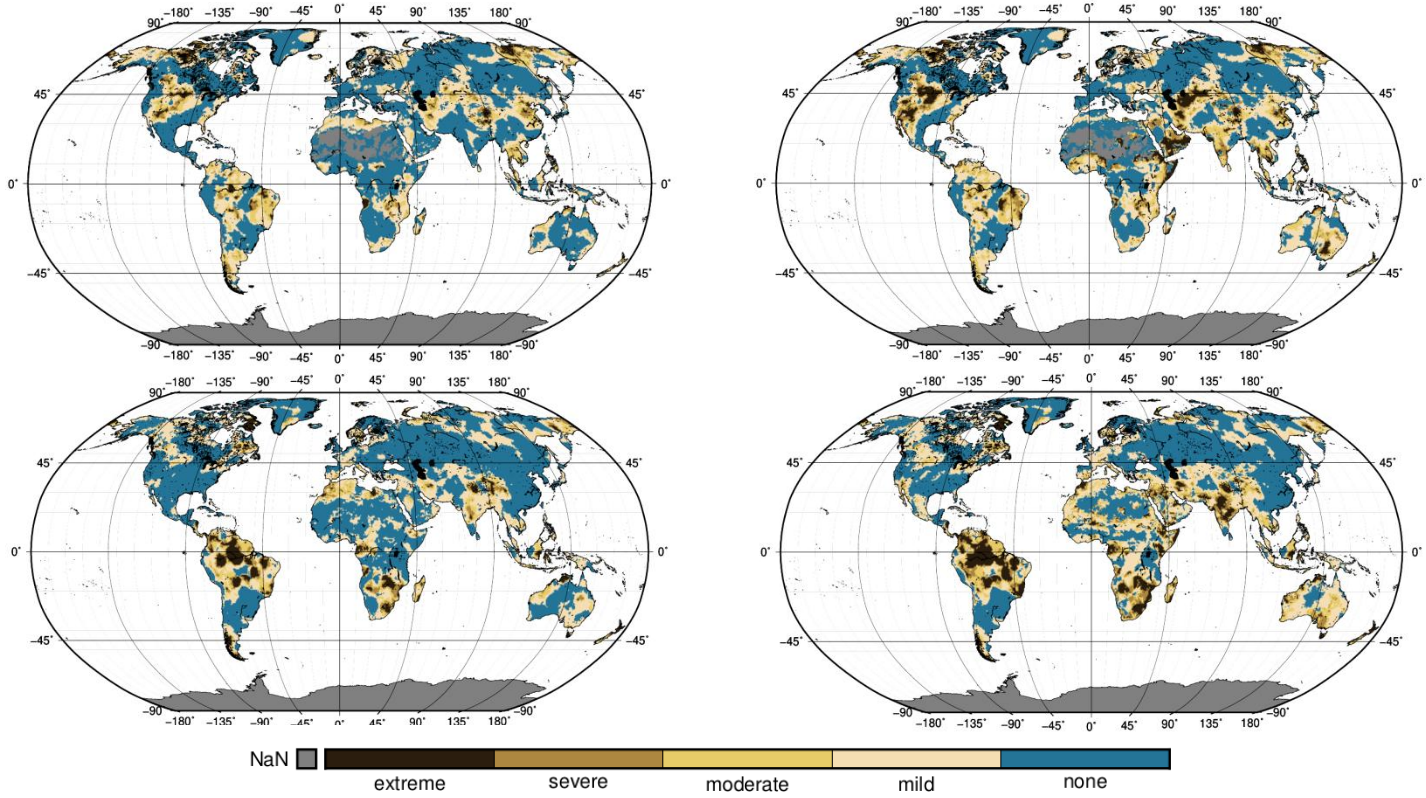
GLOBAL INDICATORS 03/2016

SPI_1

SPEI_1

SPI_6

SPEI_6



IMPLEMENTATION

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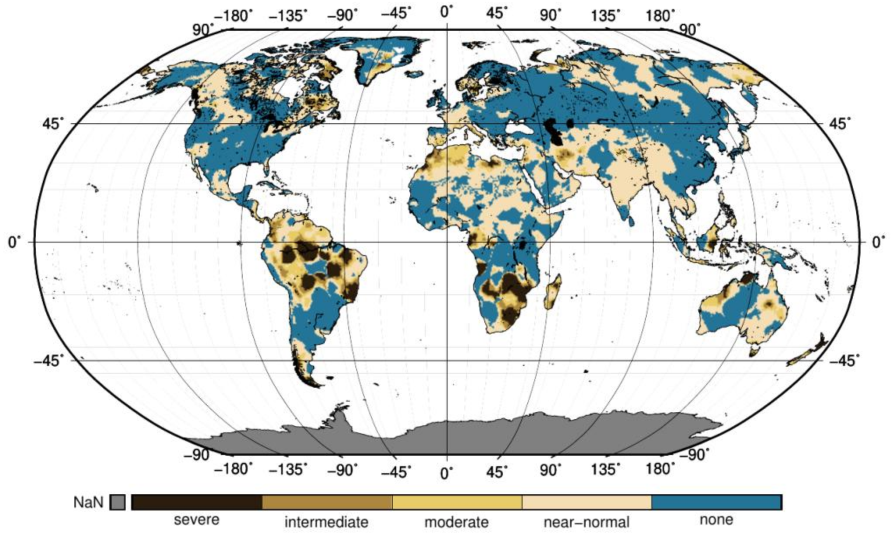
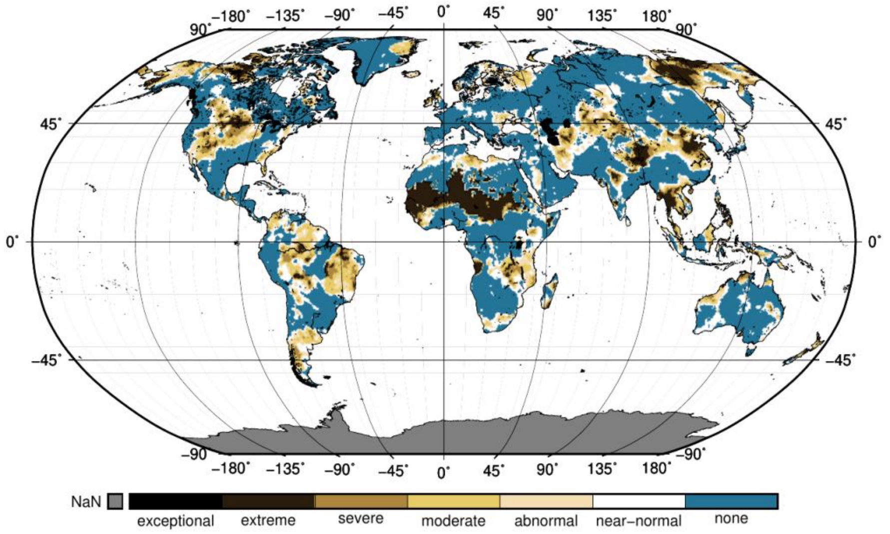
GLOBAL INDICATORS 03/2016

WASP_6



Percentiles



SUMMARY GLOBAL ANALYSIS

- Differences between SPI and SPEI
- Differences between accumulation periods of SPI, SPEI
- Accumulation period depends on observed drought event
- Drought events of varying severity visible
- Weaknesses in the desert
- Similarities of percentiles and SPI_1/ SPEI_1

REGIONAL ANALYSIS

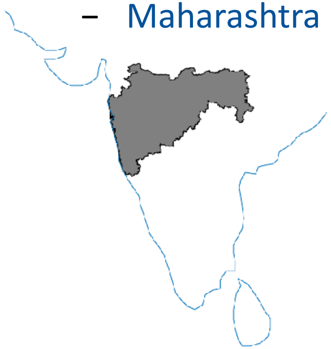
STUDY REGIONS

UNITED STATES

- Missouri river basin

WEST INDIA

- Maharashtra

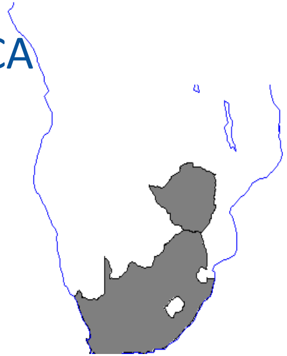


EAST BRAZIL

- Ceará

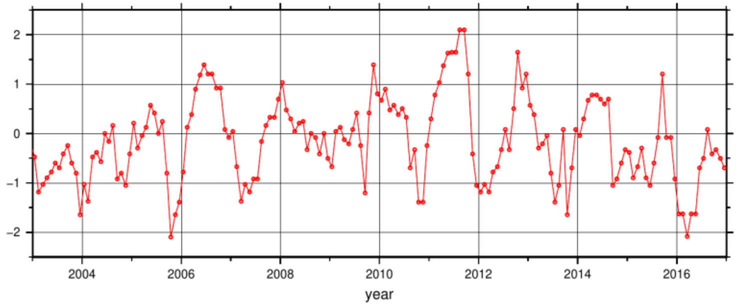
SOUTHERN AFRICA

- South Africa
- Zimbabwe



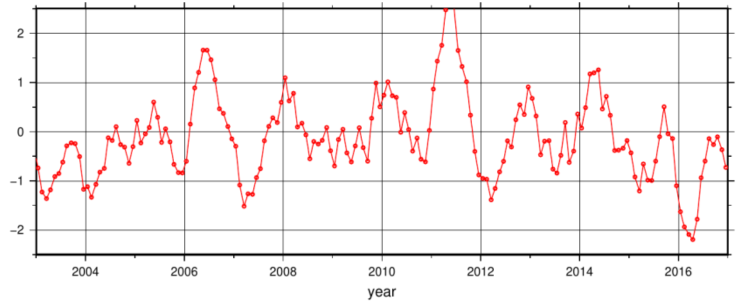
REGIONAL ANALYSIS SOUTH AFRICA

SPI6



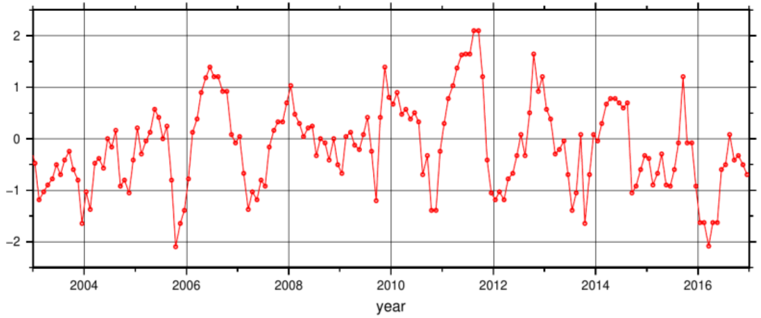
Drought types			
Mild: −1 < SPI ≤ 0	Moderate: −1.5 < SPI ≤ −1	Severe: −2 < SPI ≤ −1.5	Extreme: SPI ≤ −2

WASP6



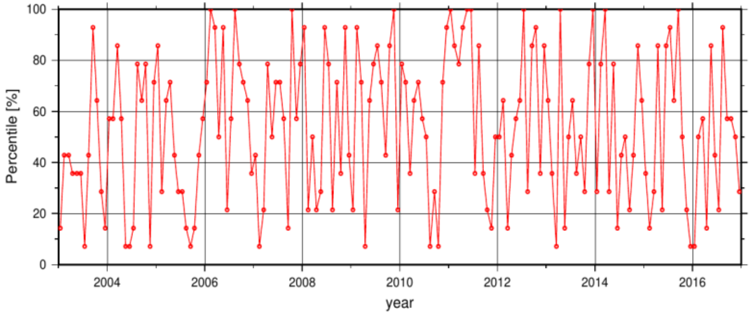
Drought types			
Near−normal: −1 < WASP ≤ 0	Moderate: −1.5 < WASP ≤ −1	Intermediate: −2 < WASP ≤ −1.5	Severe: WASP ≤ −2

SPEI6



Drought types			
Mild: −1 < SPEI ≤ 0	Moderate: −1.5 < SPEI ≤ −1	Severe: −2 < SPEI ≤ −1.5	Extreme: SPEI ≤ −2

Percentiles



Drought types				
Abnormal: 20–30	Moderate: 10–20	Severe: 5 – 10	Extreme: 2 – 5	Exceptional: 0 – 2

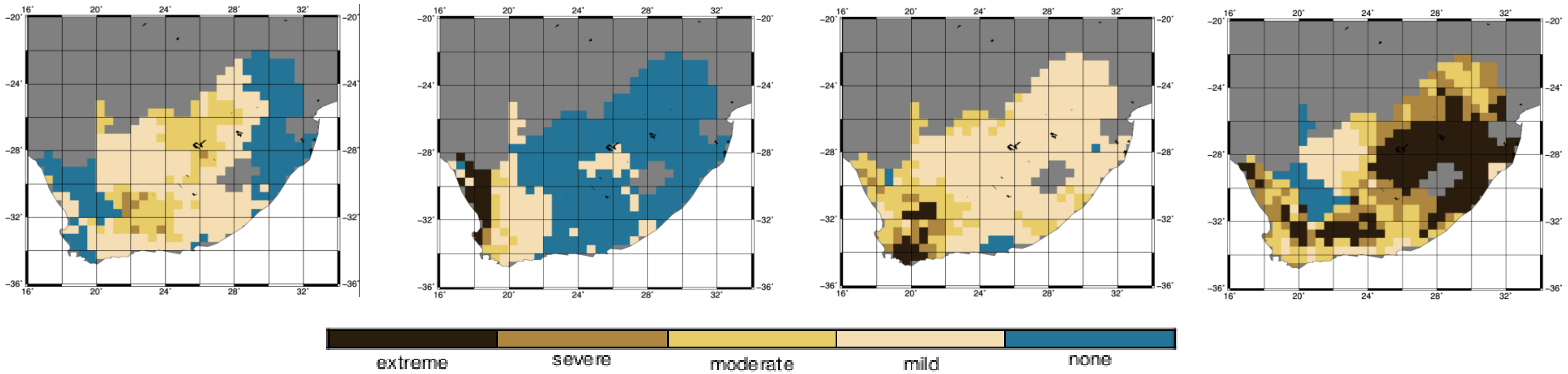
REGIONAL ANALYSIS SPEI6 SOUTH AFRICA

TEMPORAL

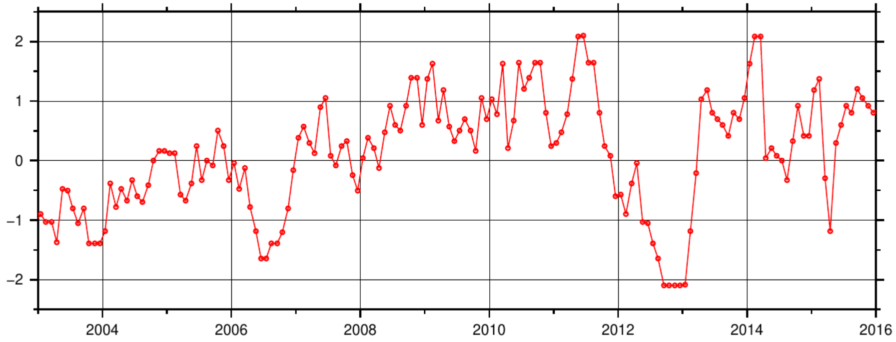
- Identified droughts in 2015/2016 (and 2004)
- Different drought intensities end 2004 and 2015/2016
- Indicator average?

SPATIAL

03/2013 03/2014 03/2015 03/2016

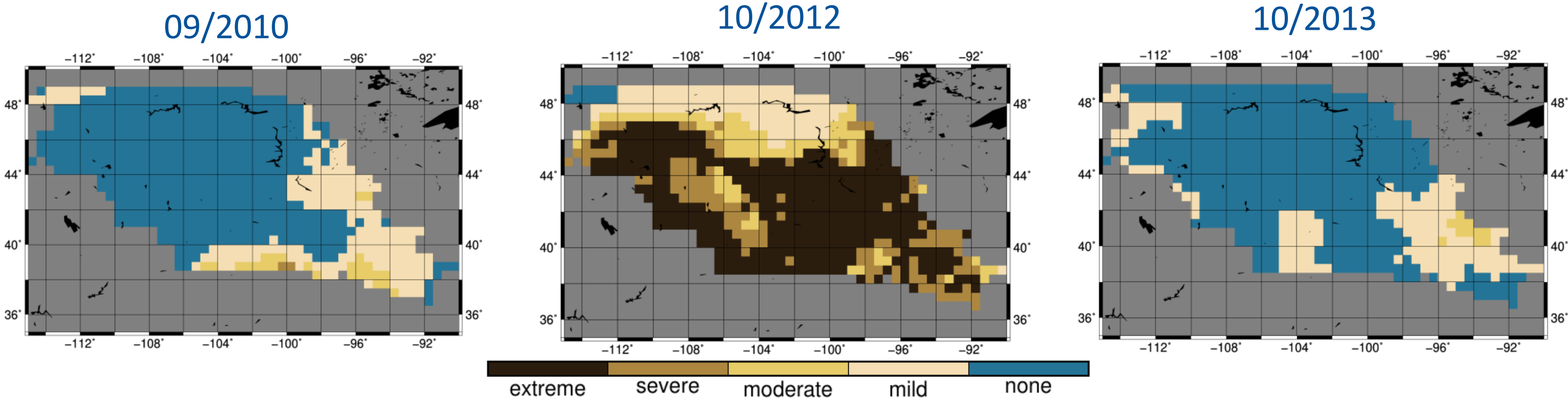


ANALYSIS SPEI6 IN THE MISSOURI RIVER BASIN

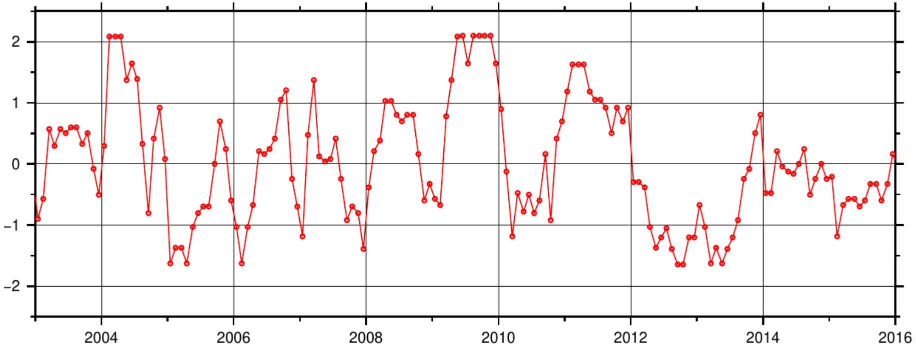


- Extreme drought in a large part of the basin in 2012, begin of 2013
- GAO report (2014)

Drought types			
Mild: −1 < SPEI ≤ 0	Moderate: −1.5 < SPEI ≤ −1	Severe: −2 < SPEI ≤ −1.5	Extreme: SPEI ≤ −2



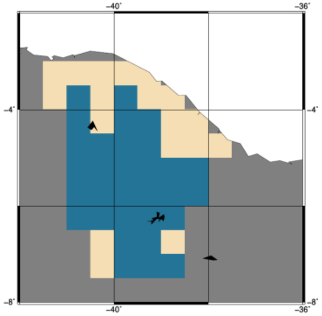
REGIONAL ANALYSIS SPEI6 IN CEARA



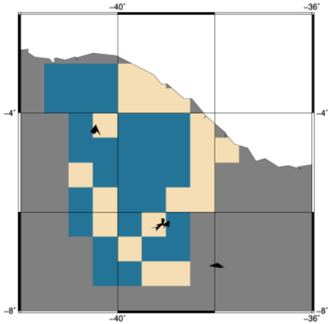
- Severe drought in Ceará in 2012/2013
- Gutiérrez et al. (2014)

Drought types			
Mild: −1 < SPEI ≤ 0	Moderate: −1.5 < SPEI ≤ −1	Severe: −2 < SPEI ≤ −1.5	Extreme: SPEI ≤ −2

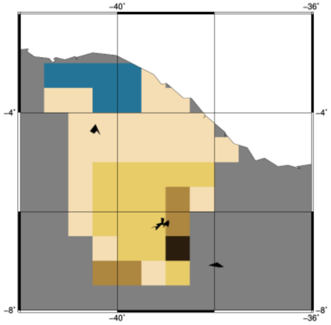
09/2010

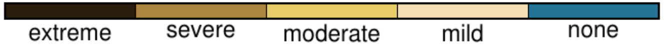


09/2011



09/2012





STUDY REGIONS – REPORTED DROUGHTS

Ceará	2010-2013, most impactful in 2012/2013 (Gutiérrez, 2014)
Maharashtra	2003, 2012 Krishna river basin (Mahajan and Dodamani, 2016)
Missouri river basin	2012/2013 (GAO report, 2014)
South Africa	2004 (EMDAT 2018, Masih 2014), 2003-2007 (Malherbe, 2016)
	2003/2004 Crocodile river catchment (Mussá, 2014)
	2015 (EM-DAT, 2018), 2015/2016 (Monyela, 2017)
Zimbabwe	2003/2004 Crocodile river catchment (Mussá, 2014)
	2007, 2010 (Masih, 2014, EM-DAT)

OPEN QUESTIONS

Spatial resolution
- Which computation of spatial average?
- …

Temporal resolution
- Usage of temporal weighting? E.g. more weight for adjacent observations
- Which input period for indicator computation?
- ...

Drought periods
- Valid for persistent and/or temporary droughts?

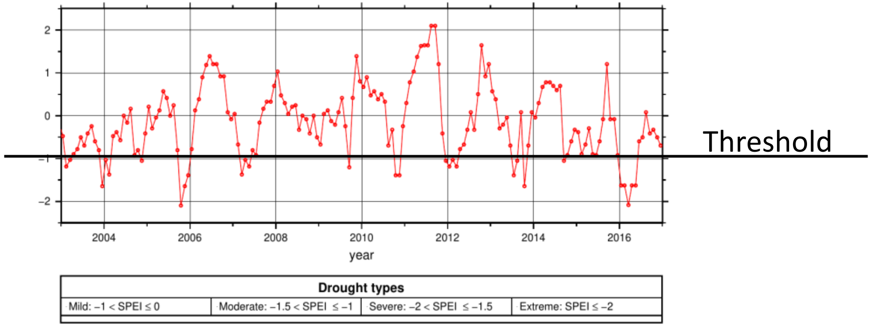
Validation
- Quantity of indicator using different input data
- Quality of indicator

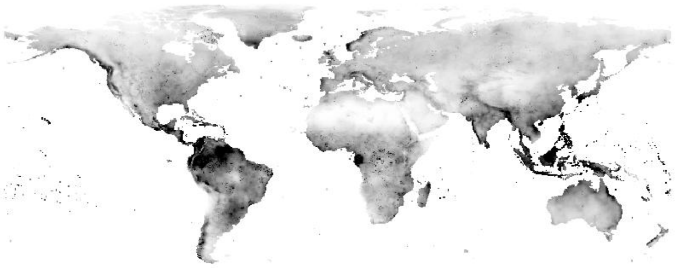
The 'best' indicator?

DROUGHT HAZARD INDEX

From monthly to static Hazard risk map

- Predefinition of extreme drought in 2.3%
- Additional assumptions





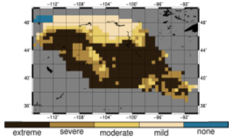
CONCLUSION

1) Meteorological droughts, context of GlobeDrought

2) Overview of global and regional drought indicators

- Time-variable drought analysis
- Introduction to static drought analysis

3) Difficulty in finding the 'best' indicator



The 'best' indicator?

Next Learning Block: Hydrological droughts

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LITERATURE

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