The sensitivity of drought variability to index and data selection

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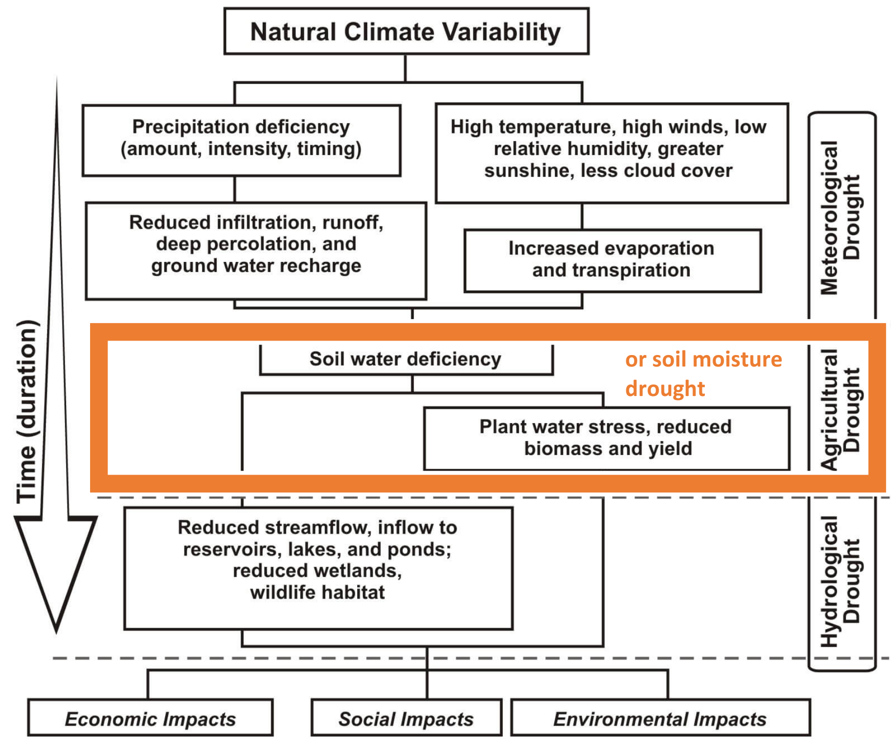
MONASH University

Research Questions

- Can a meteorological drought index sufficiently represent agricultural/ soil moisture drought for drought identification?
- What is the sensitivity of the drought index to the choice of input data?



How can we measure drought?

The different definitions of drought make it challenging to measure it

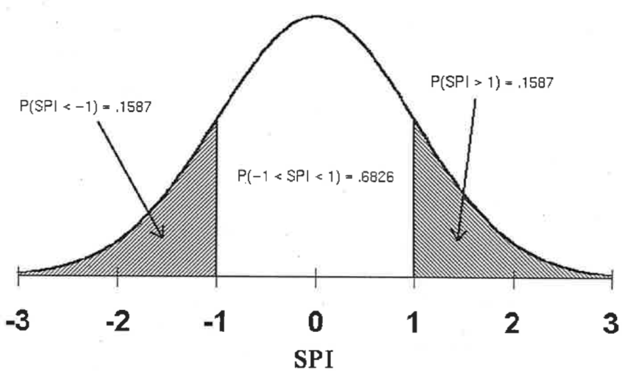
- Indices simplify the complex mechanisms of droughts and convey them as a single numeric values
  - More than 150 drought indices were developed encompassing meteorological and hydrological parameters (Zargar et al., 2011)

- Direct drought metrics measure drought effected parameters
  - Stationary soil moisture measurements are sparse and don't cover long time periods
  - Stream flow, gross primary production (GPP)

➢ This study: Two drought indices (SPI and PDSI) and modelled and satellite observed soil moisture (GLDAS and GRACE)

Standardized Precipitation Index (SPI)

- **SPI** (McKee et al, 1993) specifies drought time scales for, typically 3 to 48 months, by simply comparing precipitation with its multiyear average
- A long-term precipitation record is fitted to a probability distribution from which a normal density distribution is derived



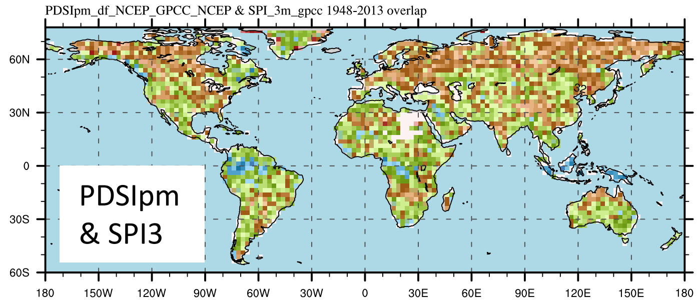
Palmer Drought Severity Index (PDSI)

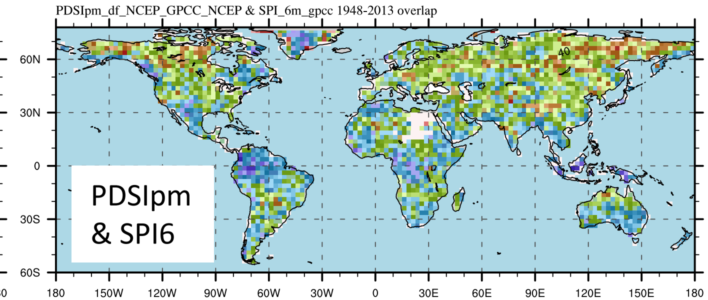
- **PDSI** (Palmer, 1965) measures the departure (d) of moisture balance from normal conditions, taking rainfall, evapotranspiration, runoff and water loss and recharge into account

$$P = \alpha_i \cdot PE + \beta_i \cdot PR + \gamma_i \cdot PRO - \delta_i \cdot PL$$

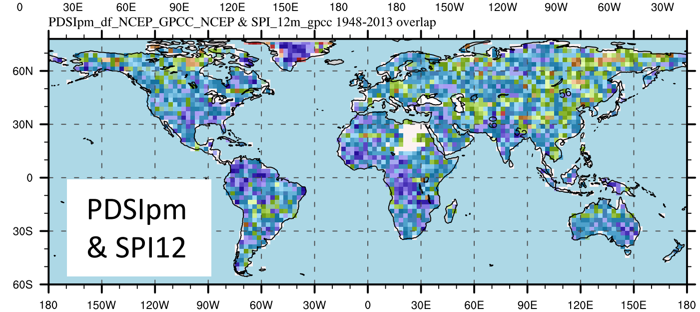
- Penmen-Monteith method requires multiple datasets and various assumptions
  - ❑ Min/max/mean temperature
  - ❑ Precipitation
  - ❑ Available water content
  - ❑ Wind speed
  - ❑ Specific humidity
  - ❑ Downward shortwave solar radiation
  - ❑ Latitude, elevation, albedo

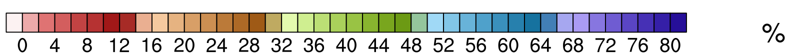
Overlap of PDSI and SPI





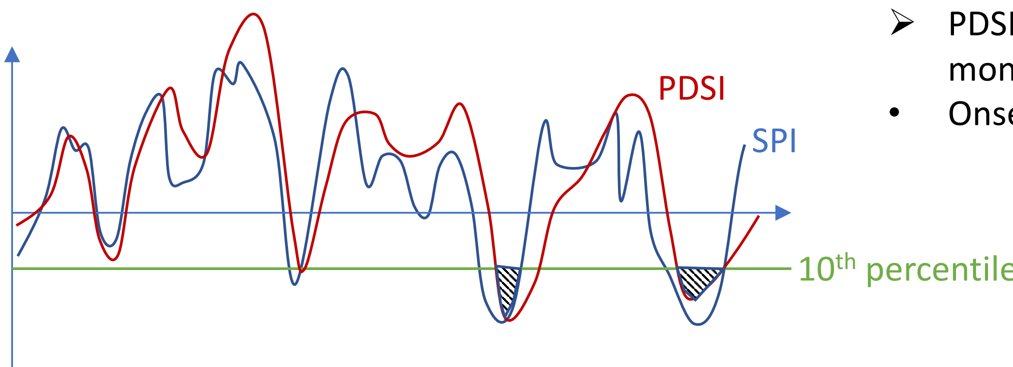
- GPCC precipitation
- NCEP temp, humidity, radiation, wind speed



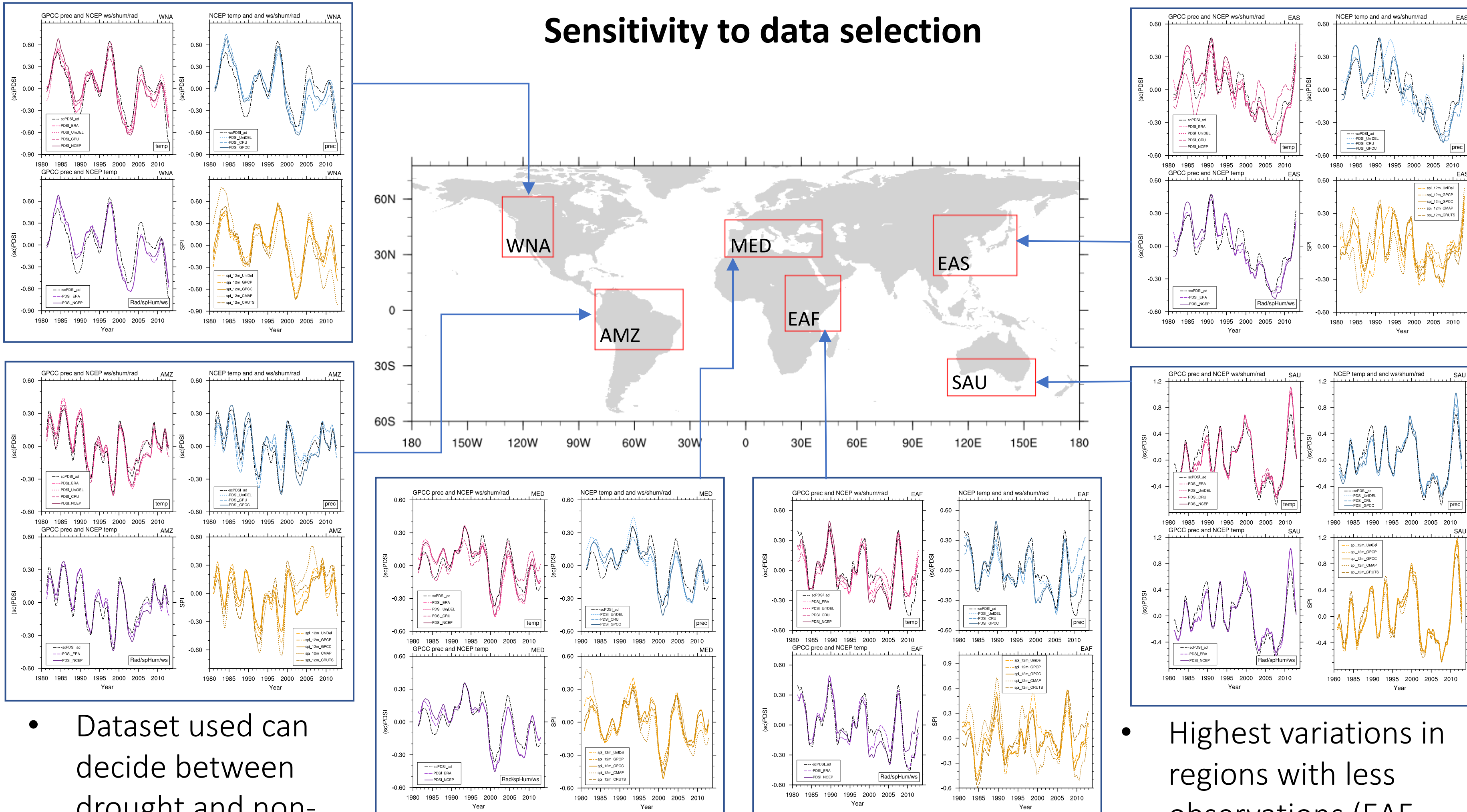


- 1948-2013
- SPI3, SPI6 and SPI12 overlap with PDSI
- SPI set as "truth"
- How much of the time the SPI is below the 10th percentile is represented in the PDSI?
- ➢ PDSI has a memory of about 12 months
- Onset and cessation can vary

Schematic:

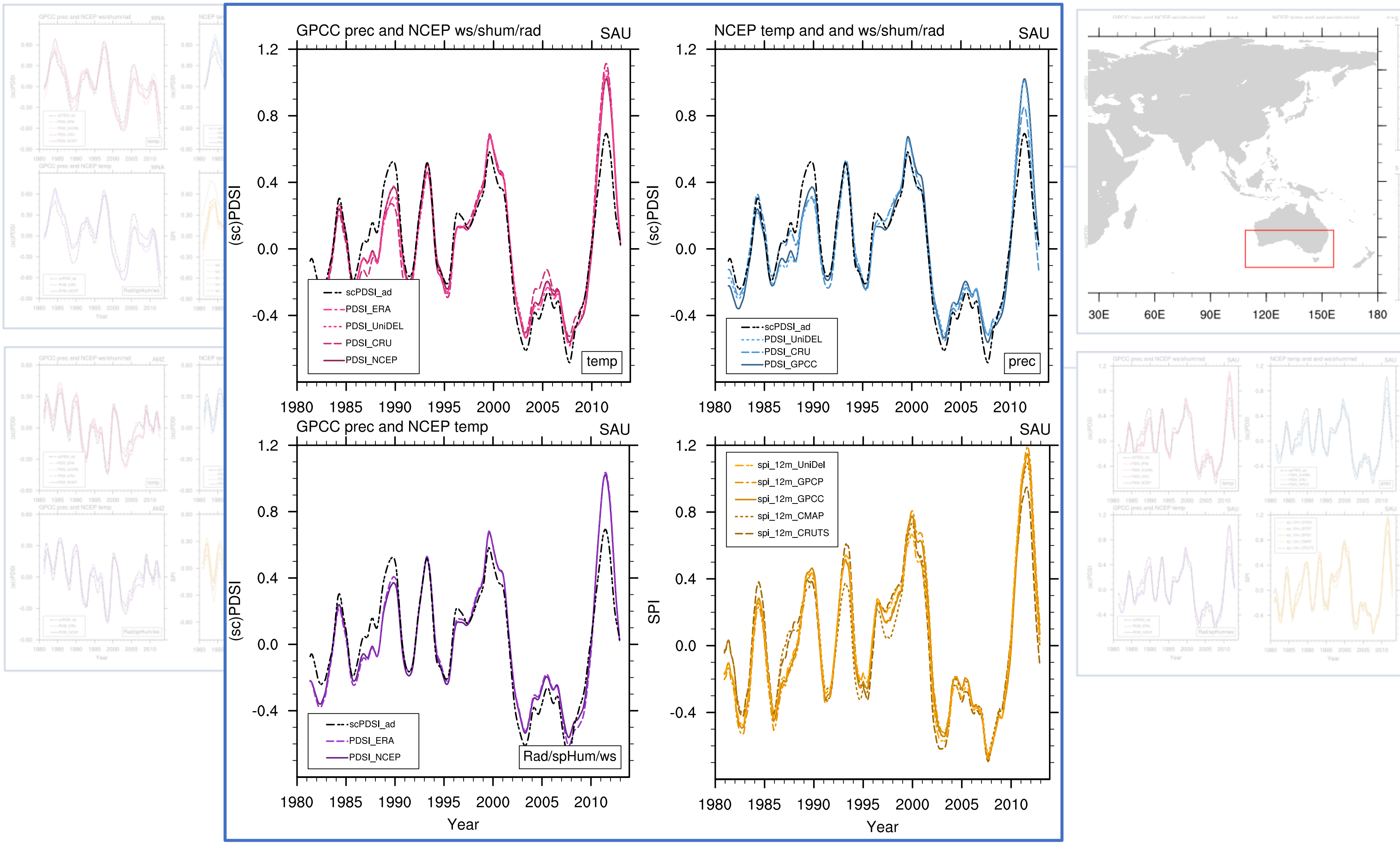


Sensitivity to data selection



- Dataset used can decide between drought and non-drought conditions

- Highest variations in regions with less observations (EAF, EAS, AMZ)


GPCC prec and NCEP ws/shum/rad
SAU
scPDSI_ad
PDSI_ERA
PDSI_UniDEL
PDSI_CRU
PDSI_NCEP
temp
(sc)PDSI
NCEP temp and and ws/shum/rad
SAU
scPDSI_ad
PDSI_UniDEL
PDSI_CRU
PDSI_GPCC
prec
GPCC prec and NCEP temp
SAU
scPDSI_ad
PDSI_ERA
PDSI_NCEP
Rad/spHum/ws
Year
SAU
spi_12m_UniDel
spi_12m_GPCP
spi_12m_GPCC
spi_12m_CMAP
spi_12m_CRUTS
SPI
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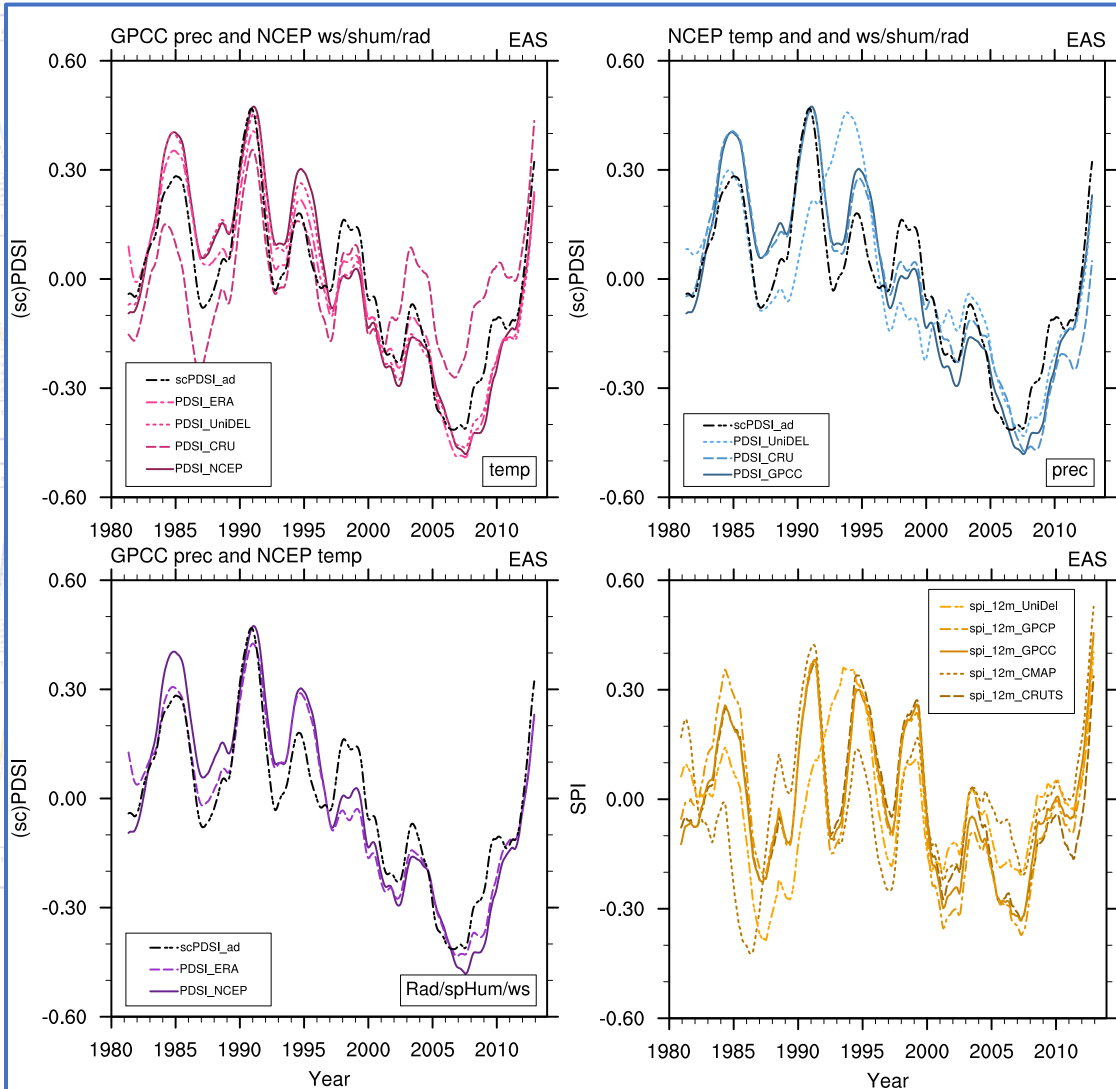

GPCC prec and NCEP ws/shum/rad
EAS
(sc)PDSI
scPDSI_ad
PDSI_ERA
PDSI_UniDEL
PDSI_CRU
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temp
NCEP temp and and ws/shum/rad
EAS
(sc)PDSI
scPDSI_ad
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GPCC prec and NCEP temp
EAS
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Rad/spHum/ws
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EAS
SPI
spi_12m_UniDel
spi_12m_GPCP
spi_12m_GPCC
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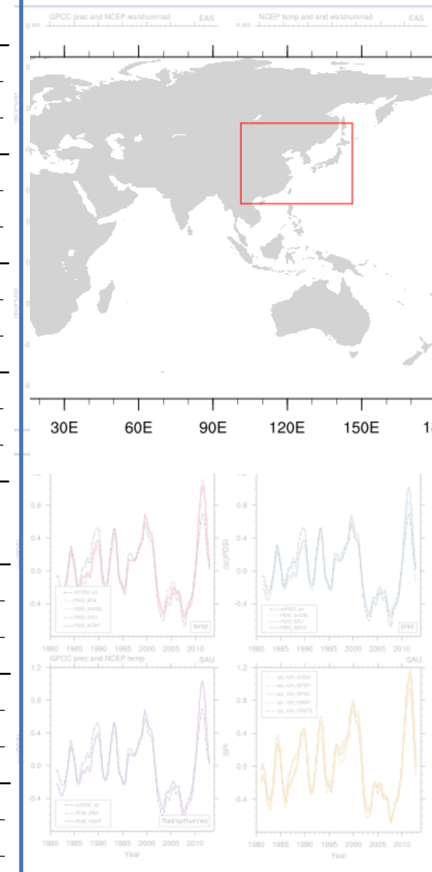
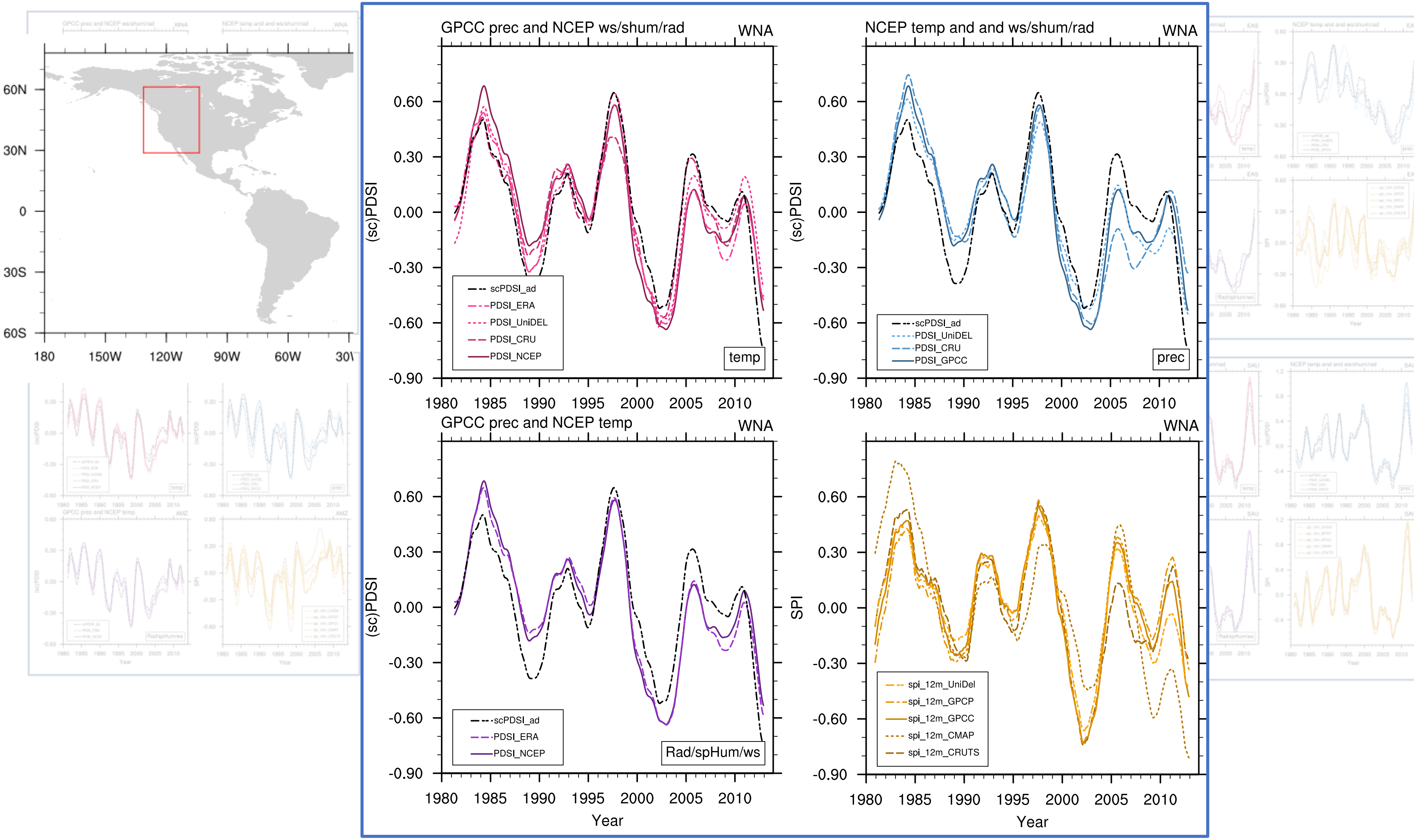
1980 1985 1990 1995 2000 2005 2010



30E 60E 90E 120E 150E 180



60N
30N
0
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150W
120W
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GPCC prec and NCEP ws/shum/rad
WNA
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temp
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prec
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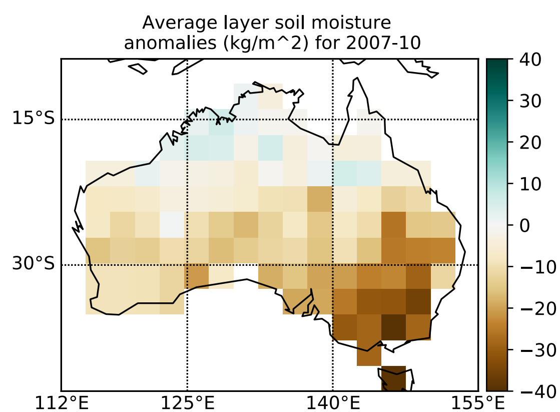
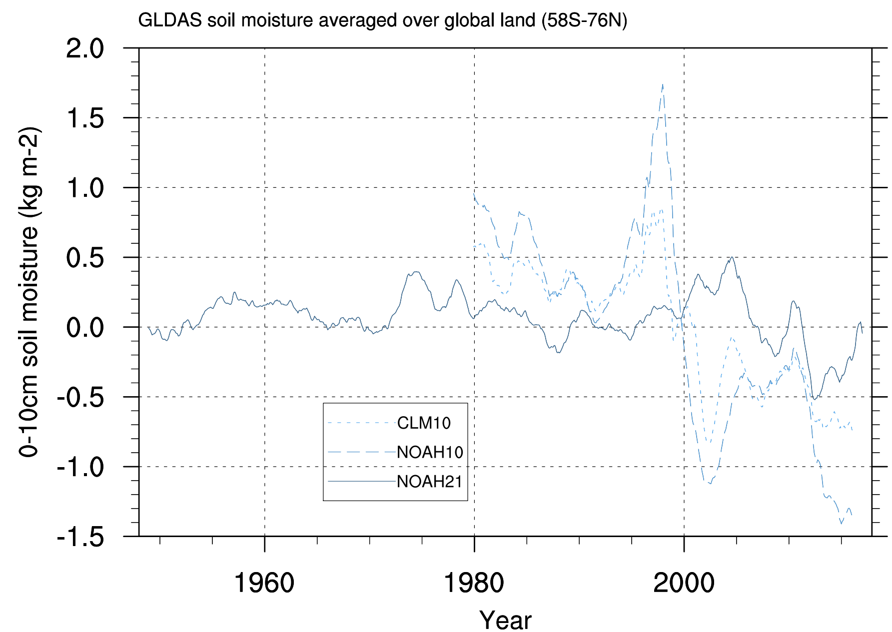
PDSI_ERA
PDSI_NCEP
Rad/spHum/ws
WNA
SPI
spi_12m_UniDel
spi_12m_GPCP
spi_12m_GPCC
spi_12m_CMAP
spi_12m_CRUTS
Year

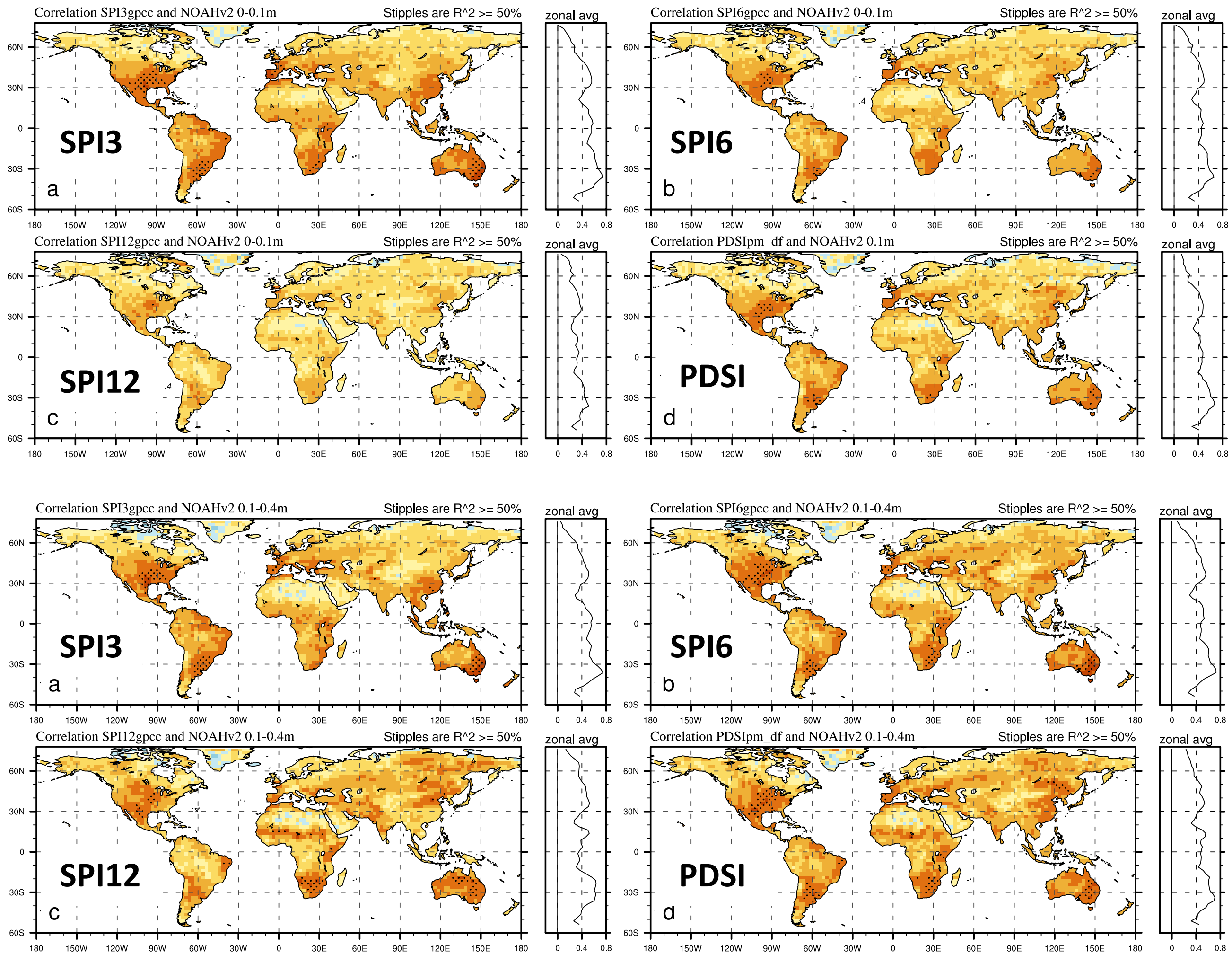
GLDAS

- **CLMv1** 10 soil layer depths up to 3.4m
- **NOAHv1/v2** 4 soil layer depths up to 2m
- Anomalies of average layer soil moisture
- estimate terrestrial water and energy storage
- v1 forcings: NCEP's GDAS, disaggregated CMAP, and AFWA radiation datasets
- v2 forcings: The Princeton Global Meteorological Forcing Dataset





Correlation of drought indices with GLDAS soil moisture levels



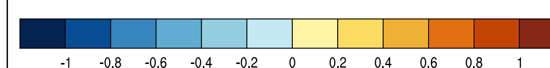
GLDAS NOAHv2
0-10cm

- ➢ SPI3 best co-variability

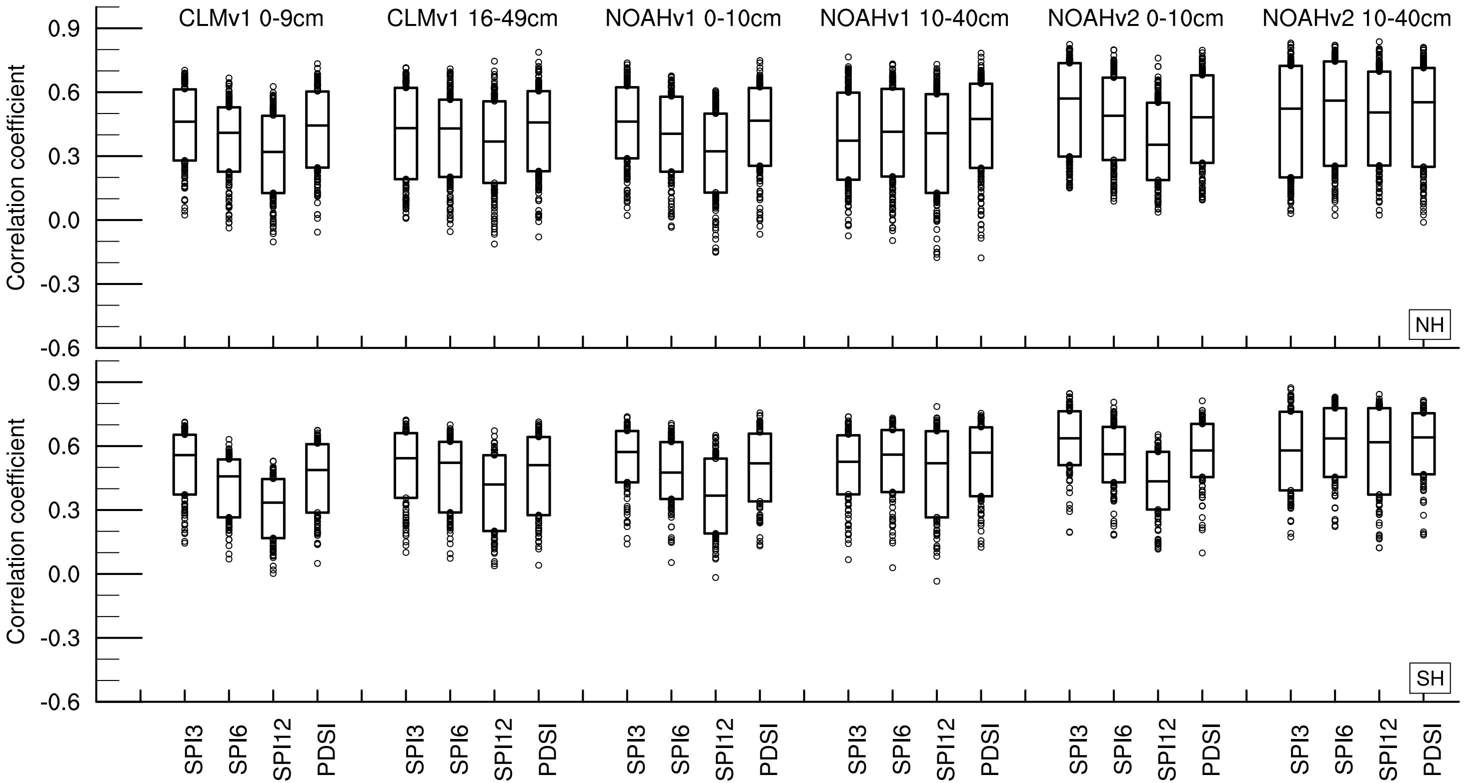
- SPI uses GPCC precipitation
- 1948-2013
- PDSI uses GPCC precipitation, NCEP temperature, solar radiation, wind speed and specific humidity

GLDAS NOAHv2
10-40cm

- ➢ SPI6 best co-variability

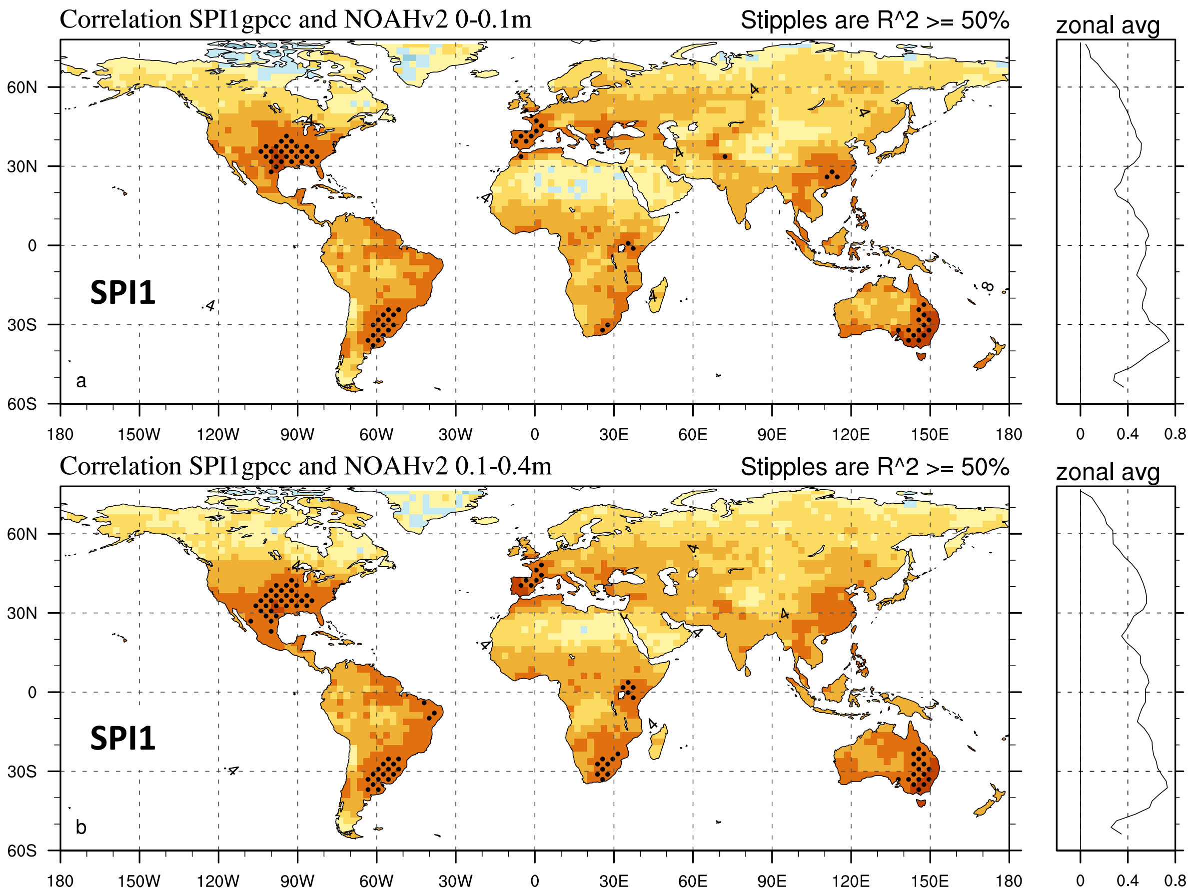


High correlations of DIs in the subtropics



- ➢ Inclusion of ET is not crucial to identify agricultural drought in the mid latitudes
- ➢ Variations in soil moisture in the subtropics is mainly driven by precipitation

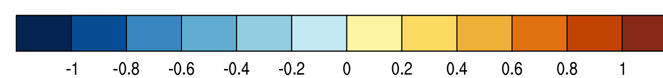
Correlation of SPI1 with GLDAS soil moisture levels

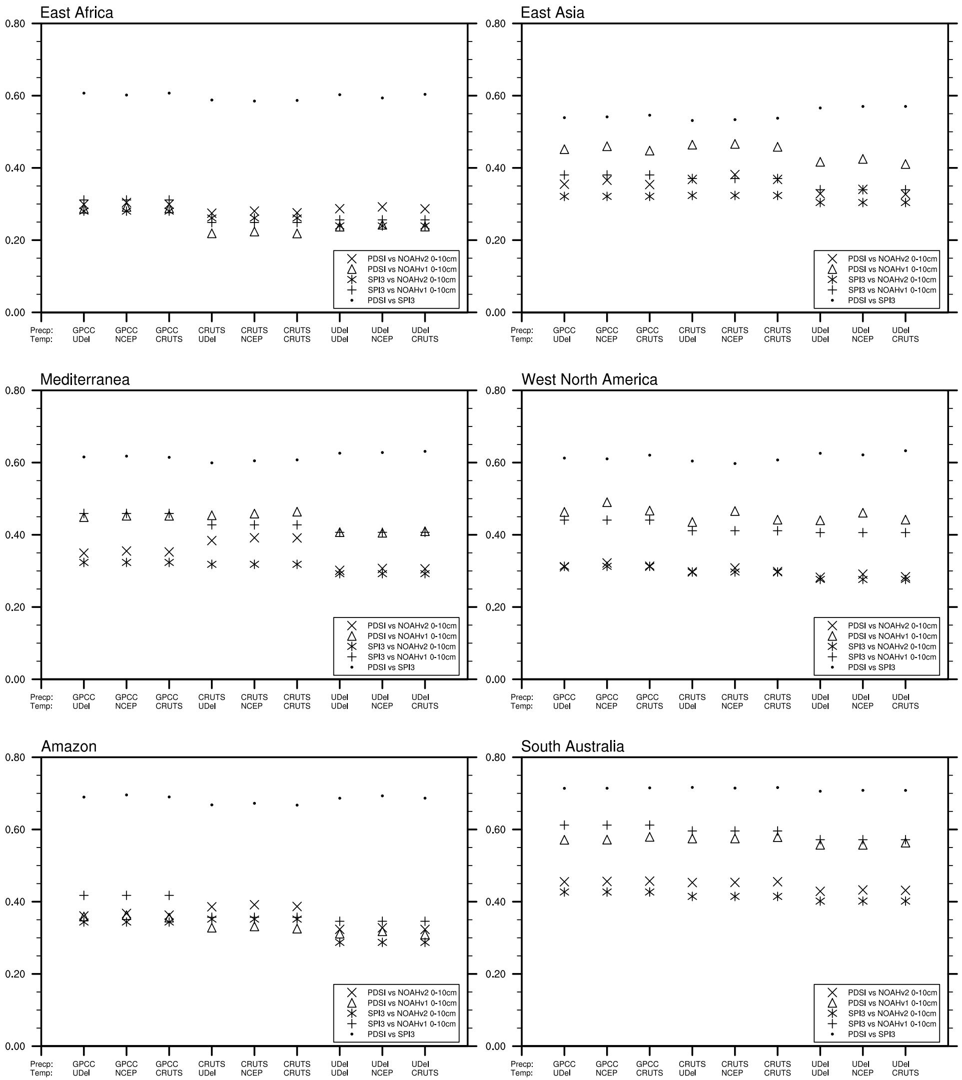


GLDAS NOAHv2 0-10cm

- SPI uses GPCC precipitation

GLDAS NOAHv2 10-40cm





Inclusion of evapotranspiration vs choice of dataset for 0-10cm soil moisture

Temperature data:

- UDel
- CRUTS
- NCEP

Precipiation data:

- UDel
- CRUTS
- GPCC

➢ Choice of data in most regions more important than ET (MED, EAF, WNA, AMZ)

Summary

- SPI identifies droughts in low to mid latitudes (15˚-40˚N/S) as well as the PDSI identifies droughts.

- Using longer time scales for calculating precipitation anomalies (> 6 months) identifies droughts as well as soil moisture estimates, which include evapotranspiration

- Attention is required when selecting datasets for computing drought indices, depending on the region of interest


Thank you very much for
your attention!
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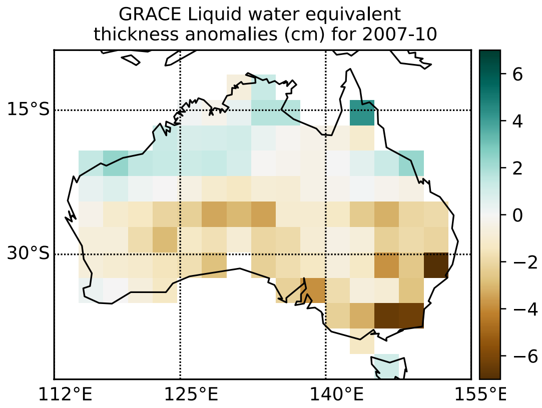
GRACE JPL

- monthly anomalies of liquid water equivalent thickness (**lwe**)
- derived from temporal gravity field variations measured by the GRACE satellite, based on the RL05 spherical harmonics
- Unlimited depth



GLDAS

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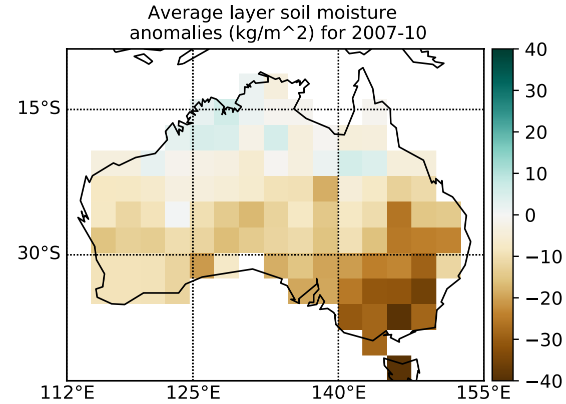
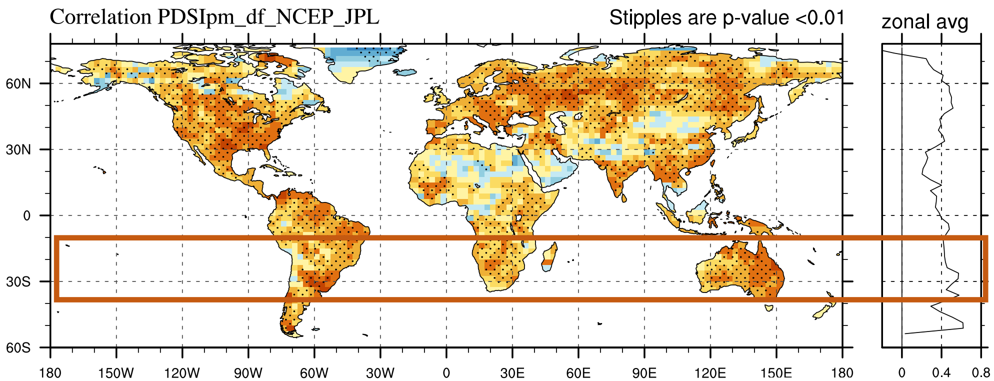
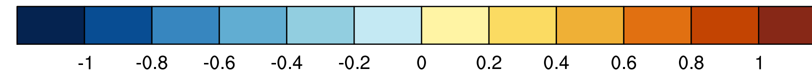
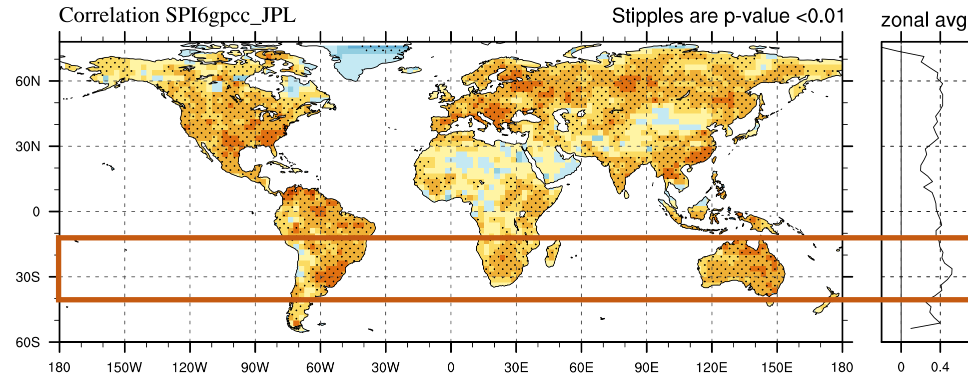


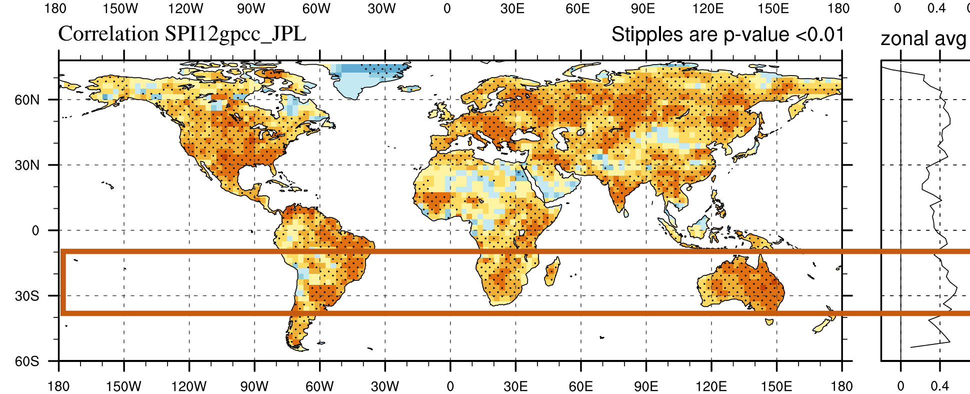


Correlation with GRACE JPL TWS





- Weak correlations in dry and high altitude/latitude regions
- Higher correlations in the low to mid latitudes (~15 - 40˚S, ~30 - 55˚N)
- PDSI does not perform much better than SPI9/12 showing that the SPI captures deeper soil moisture as well



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Utilized data

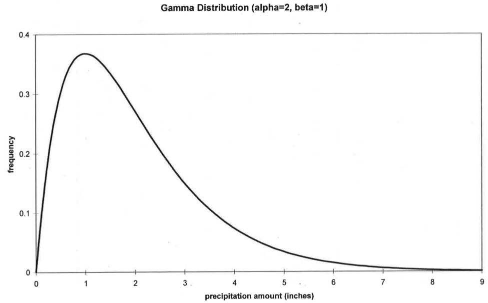
Data	Years available	Variables used
ERA Interim	1979-2016	Wind speed, spec. humidity, dw sw solar radiation, max/min temperature
NCEP reanalysis II	1948-2016	As above, but mean temperature, precipitation
GPCP	1979-2016	Precipitation
GPCC	1900-2013	Precipitation
AWC	constant	Available water content
GRACE JPL	2002-2016	monthly anomalies of liquid water equivalent thickness
GLDAS CLM/NOAH	1979-2016	Average layer soil moisture
CRU TS v.4.01	1901-2016	Precipitation, min/max temperature
scPDSI	1850-2014	scPDSI (Dai et al., 2011)
CMAP	1979-2017	precipitation

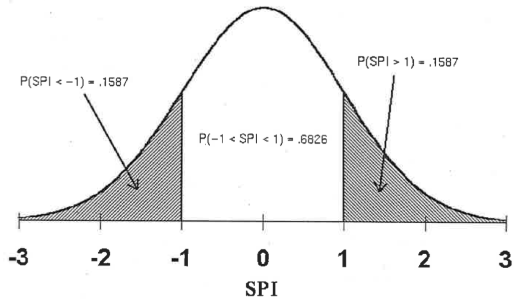
SPI PDSI Both

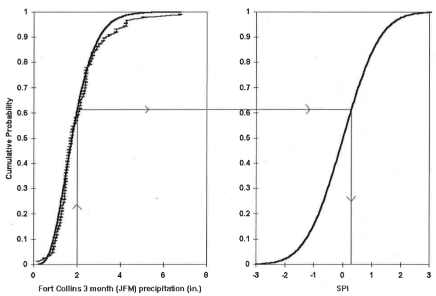
➔ Regridded to 2.5˚ x 2.5˚

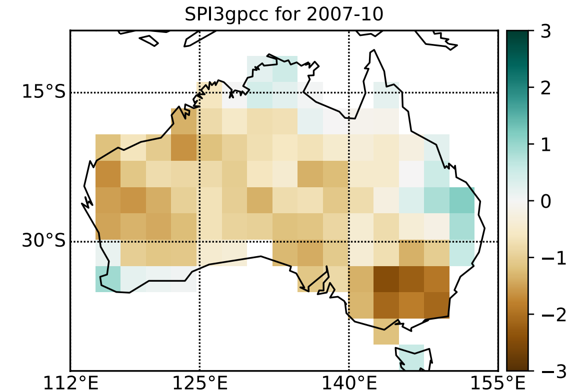
Standardized Precipitation Index (SPI)

- SPI (McKee et al, 1993) specifies drought time scales for, typically 3 to 48 months, by simply comparing precipitation with its multiyear average
- A long-term precipitation record is fitted to a probability distribution from which a normal density distribution is derived



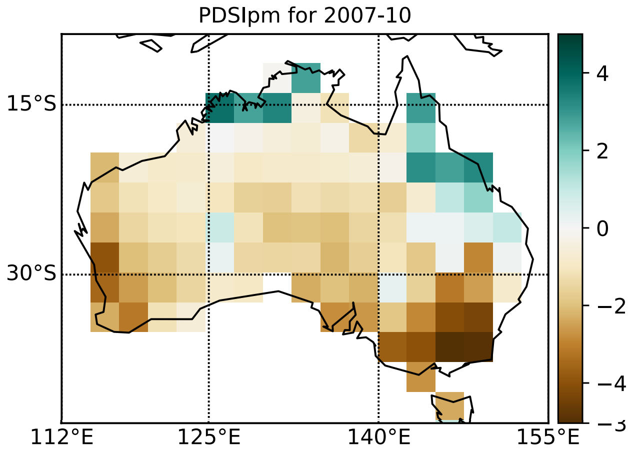


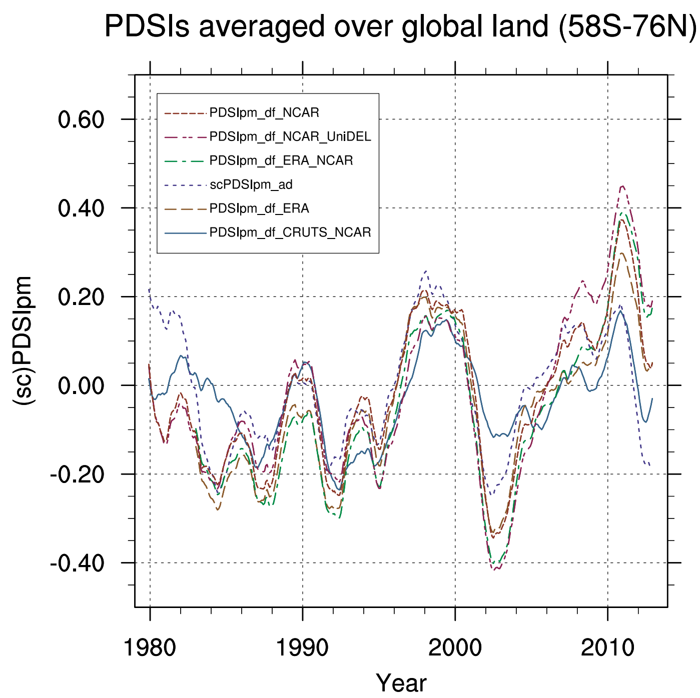


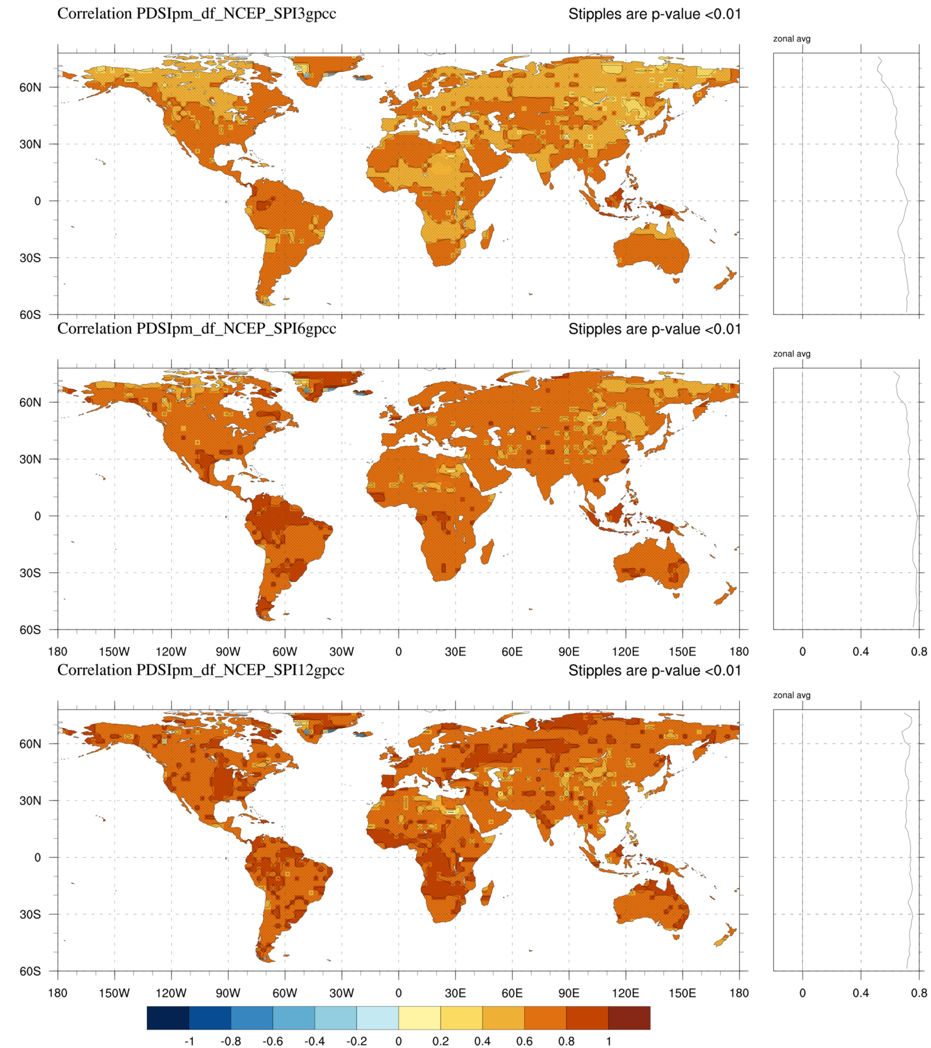


Palmer Drought Severity Index (PDSI)

- Penmen-Monteigh method requires multiple datasets and various assumptions
  - ❑ Min/max/mean temperature
  - ❑ Precipitation
  - ❑ Available water content
  - ❑ Wind speed
  - ❑ Specific humidity
  - ❑ Downward shortwave solar radiation
  - ❑ Latitude, elevation, albedo





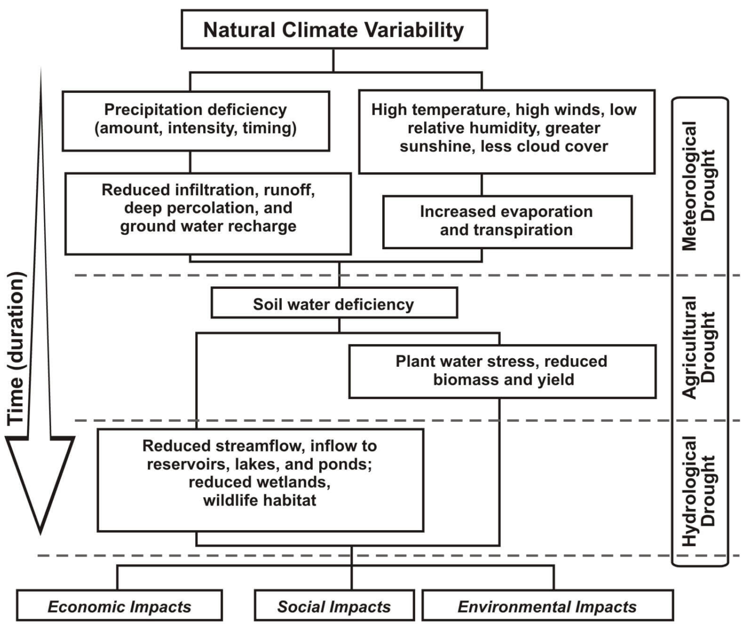


Level of uncertainty in measuring drought

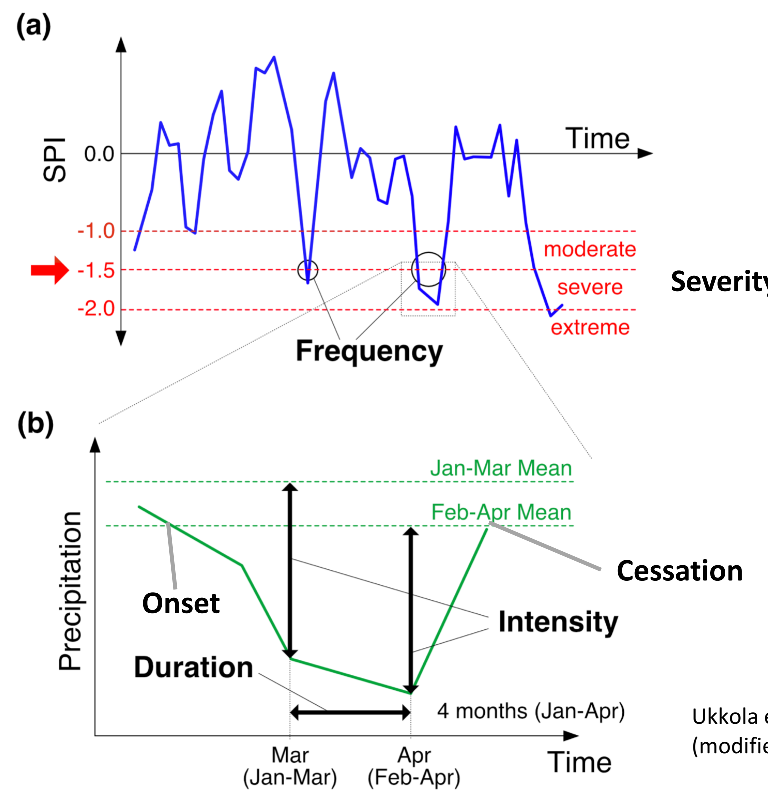
- Depends on datasets used
- PDSI and SPI are well correlated (1948-2013)

What is a drought?

- Drought research differentiates between drought *types* and *characteristics*



Source: http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx



Ukkola et al. 2017 (modified)

Palmer Drought Severity Index (PDSI)

Self-calibration method (scPDSI) (Dai 2011, Wells & Hayes 2004)

- PDSI model uses constant parameter for local climate
- Local distribution of PDSI values is sometimes skewed → rescaling
- Calibrated parameter very similar to original
- Calibration can exaggerate or diminish the trend