Water Cycle Intensification Indicator (WCI)

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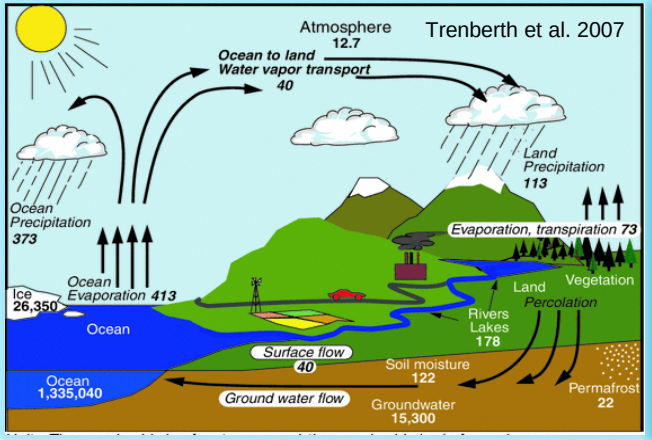
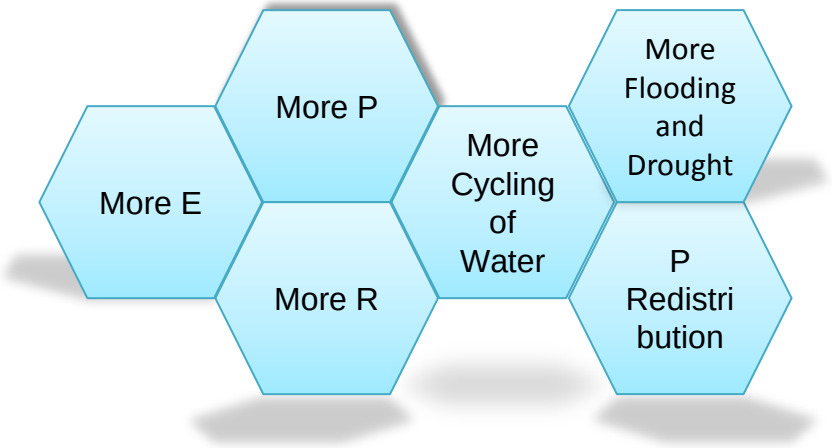


Water cycle is the process by which water is evaporated from ocean and land, transported by atmosphere, and condensed as clouds and precipitation, eventually falling to land and oceans.

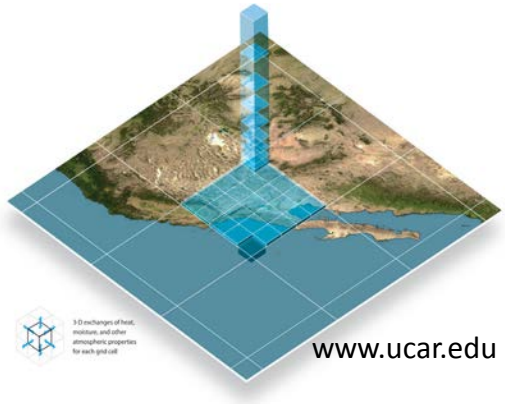
Global warming intensifies the water cycle (Held and Soden 2006, Huntington et al. 2006, Wild et al. 2008, Gallant and Karoly 2010, Durak et al. 2012, Syed et al 2012)

Intensification of Water Cycle



Project Objective

We will develop and test potentially spatially- and temporally-scalable Water Cycle Intensification Indicators (WCI) using NASA observations, reanalyses and model output in support of the National Climate Assessment (NCA).



Methodology

Terrestrial water balance equation is

$$\frac{\partial S}{\partial t} = P - E - R$$

S is Terrestrial storage, P is precipitation, E is evaporation, R is runoff.

Atmospheric water balance equation is

$$\frac{\partial W}{\partial t} = C + E - P$$

W is atmospheric water content, C is moisture convergence flux.

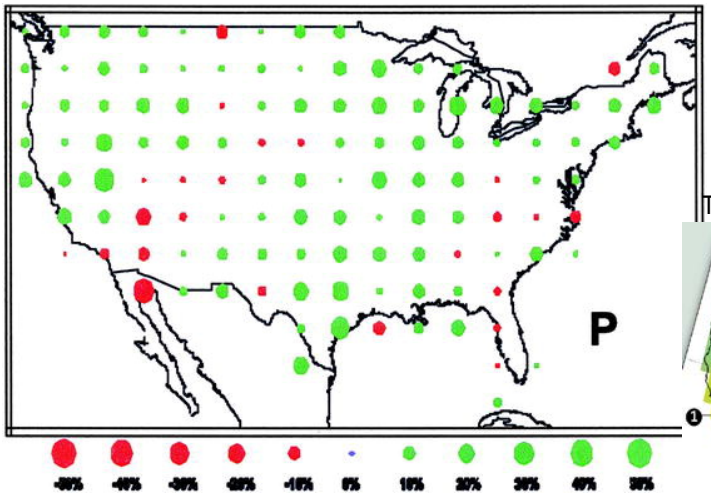
Data

Primarily NASA-based observations, Reanalysis and model products:

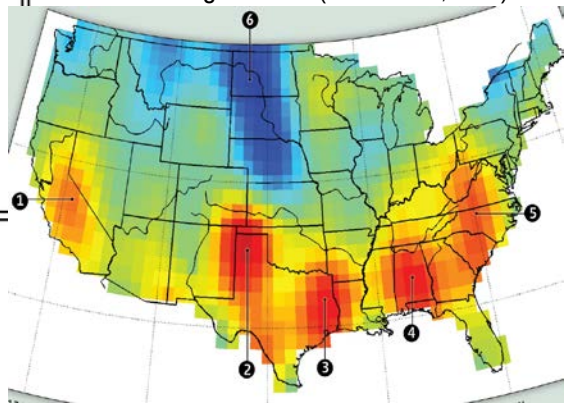
- GPCP
- NVAP-M
- GRACE
- MERRA
- MEaSURES
- NCA-LDAS
- GISS E2

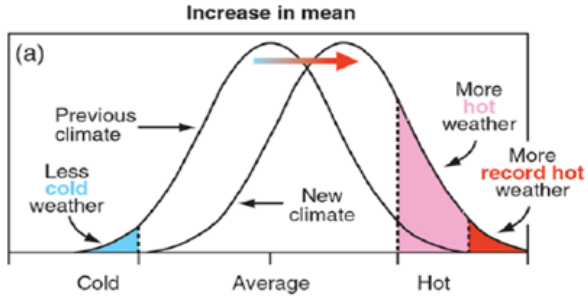
Background

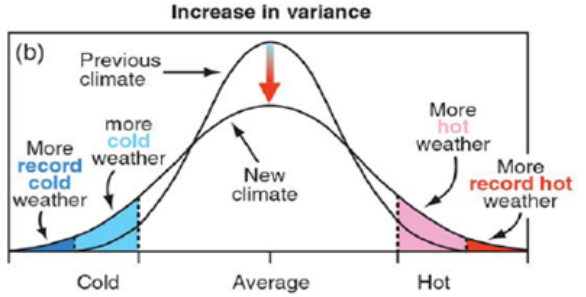
Precipitation Trends (Griosman et al., 2004).

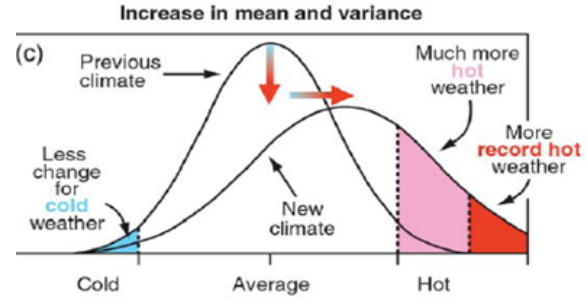


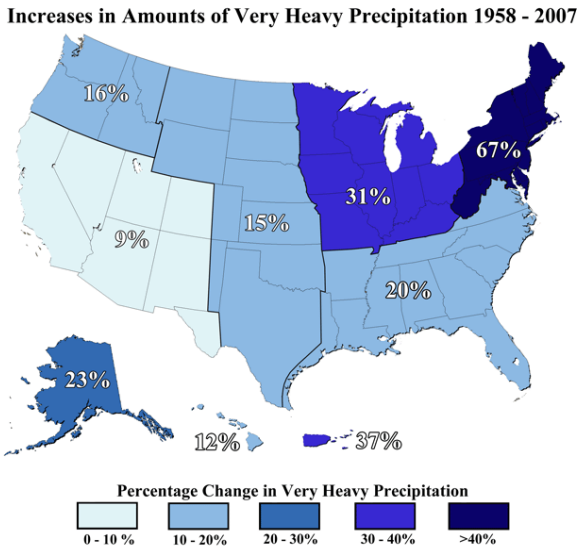
Total water storage Trends (Rodell et al., 2013).

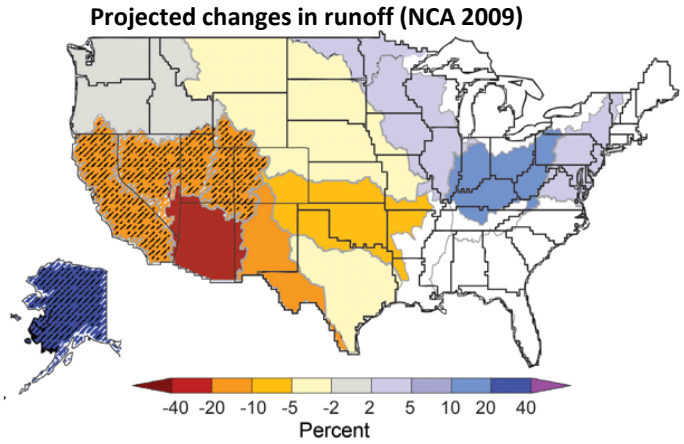












gure 3: Potential changes in the distribution of imate variables, with subsequent changes in the isk of extremes. (Folland et al., 2001)

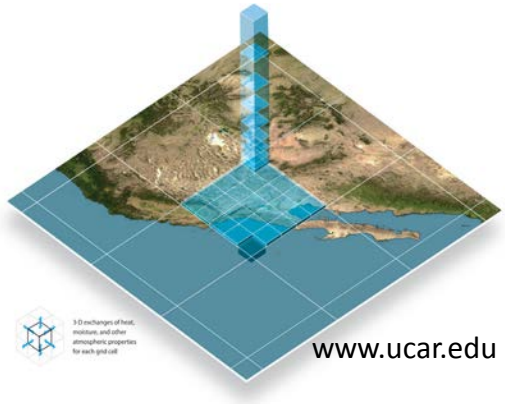
Proposed Water Cycle Intensification Indicator (WCI) suite

Trend (mean)	Dry Extreme (daily lower 10th percentile)	Wet Extreme (daily upper 10th percentile)
P trend	Dry P extreme	Wet P extreme
E trend	Dry E extreme	Wet E extreme
R trend	Dry R extreme	Wet R extreme
C trend	Dry C extreme	Wet C extreme
S trend	Dry S extreme	Wet S extreme
W trend	Dry W extreme	Wet W extreme
Composite trend	Composite dry extreme	Composite wet extreme
	Composite area dry extreme (not gridded)	Composite area wet extreme (not gridded)
Composite intensification (includes all primary trend and extreme indicators)		

WCI Application

Demonstrate Indicator Functionality

develop and test spatially- and temporally-scalable Water Cycle intensification Indicators (WCI), including a vertically integrated gridded composite of primary water cycle trends and extremes, integrated and weighted through water balance concepts.



Scalable

Scalable in time

Monthly, Seasonal, Annual

Scalable in Space

Point, Region, CONUS

Percent of area in extreme

Composite

Trend consistency

Normalized combinations

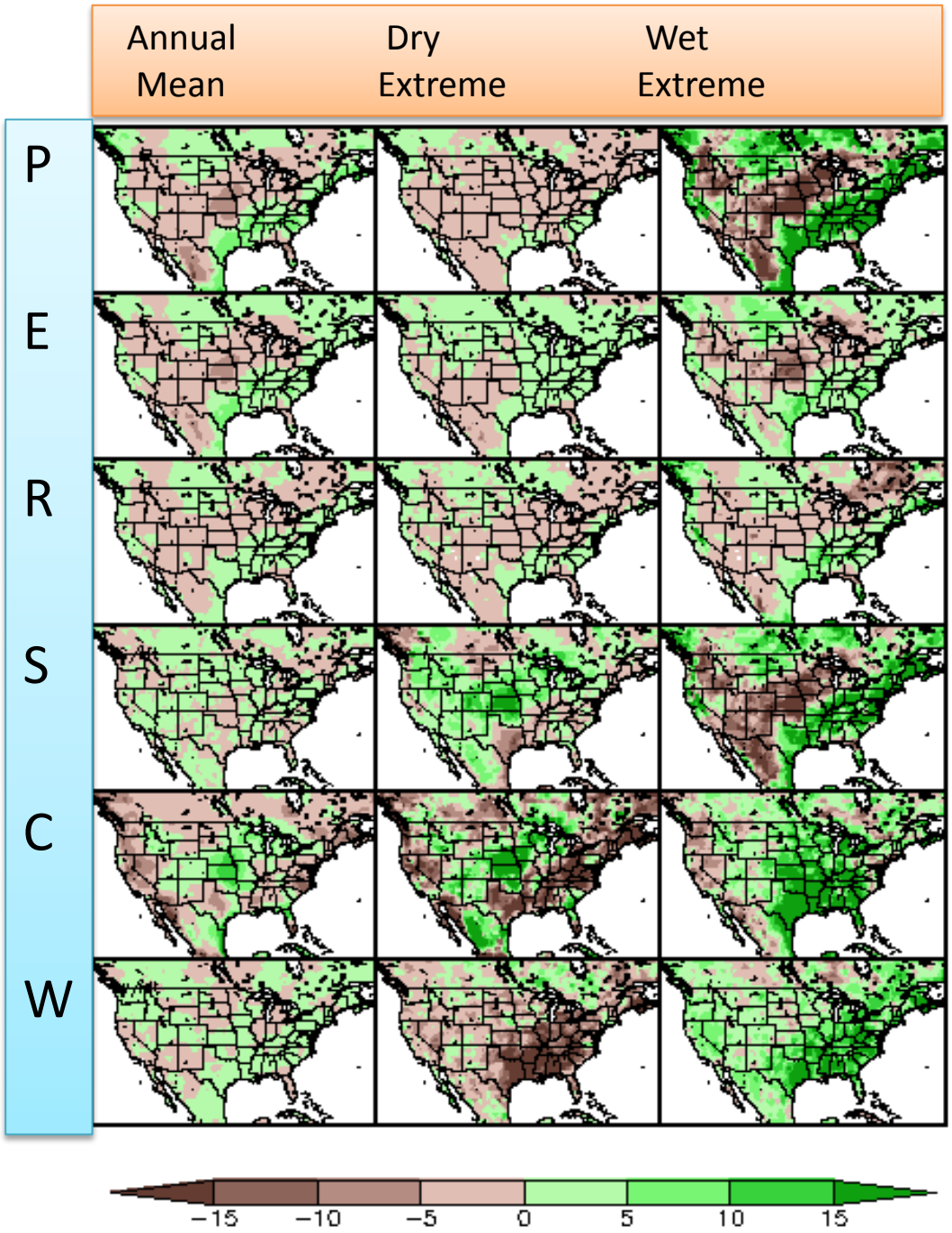
Water balance summations

Assess Trends in Water Cycle Variables

- Mann-Kendall trend significance test (Mann 1945; Kendall 1975)
  - rank-based nonparametric procedure
  - resistant to the effect of extreme values and to deviations from a linear relationship
  - doesn't make any assumptions on the distribution of the data
- Magnitude of trend is calculated by Kendall's tau-based estimator proposed by Sen (1968)

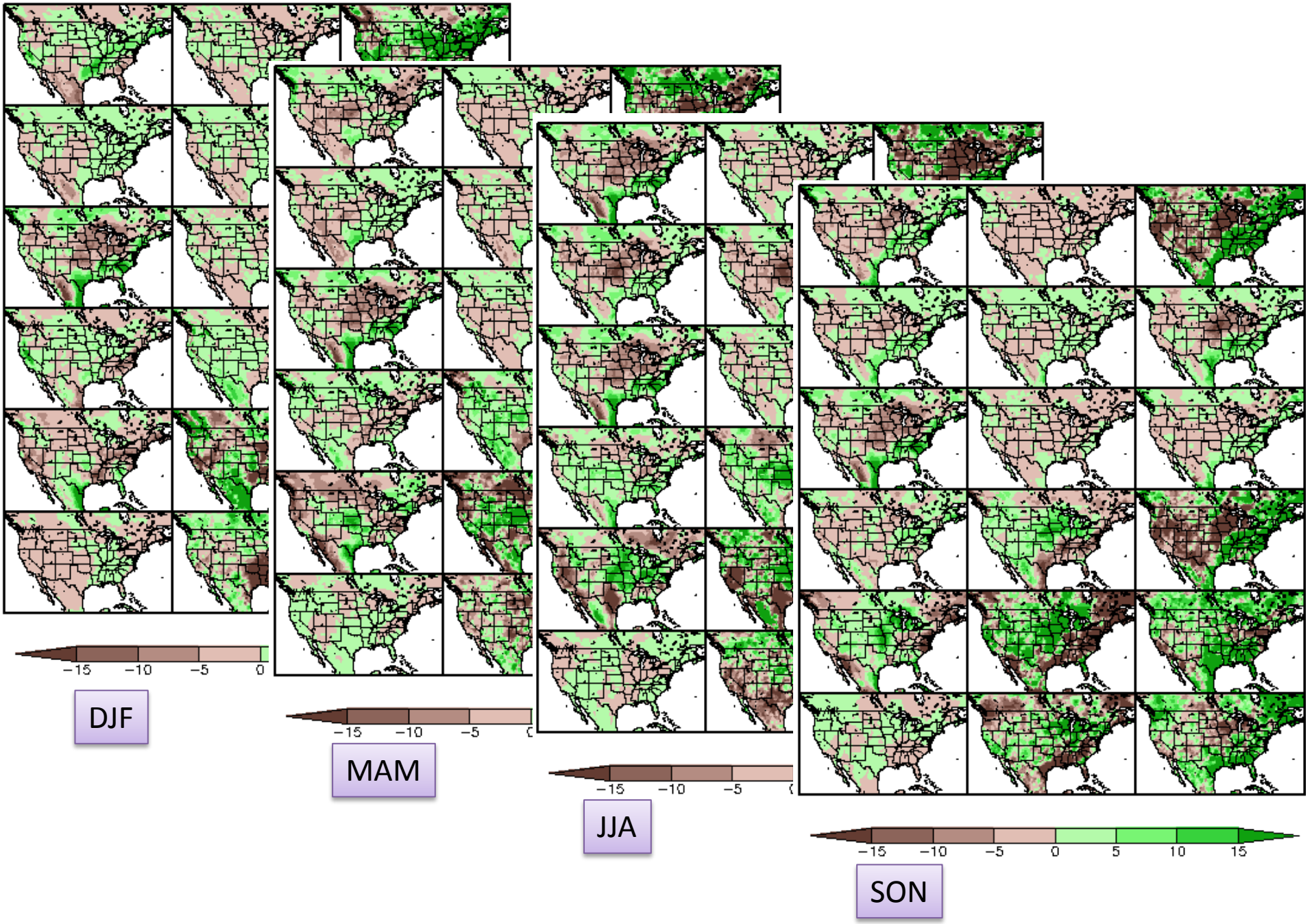
Scalable Indicators: Temporal

Trend (mm/year) of Annual Mean, **Dry Extreme** (Daily 5% percentile) and **Wet Extreme** (Daily 95% percentile) from MERRA Water Cycle Variables during 1979-2012



Trend is generally significant at 5% level over the US.

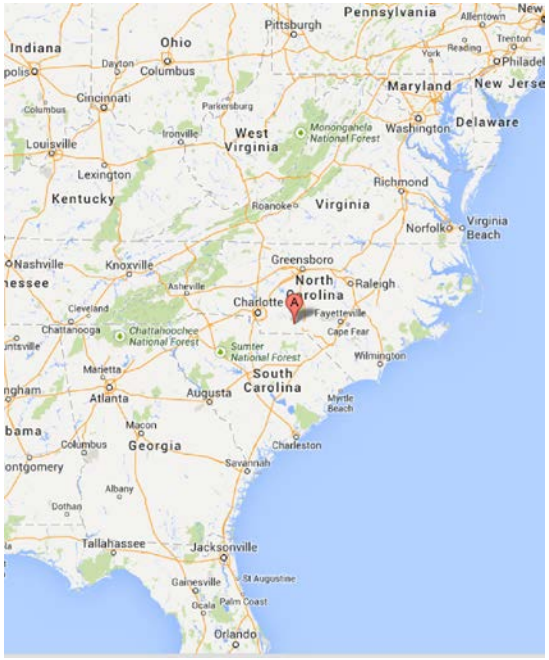
Trend (mm/year) of Seasonal Mean, Dry Extreme and Wet Extreme from MERRA during 1979-2012

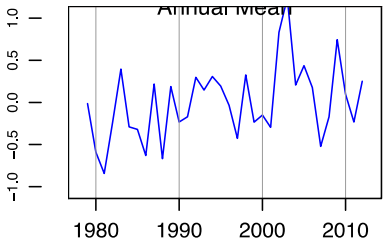


Scalable Indicators: Spatial

Time Series and Trend of Annual Mean, Dry Extreme and Wet Extreme Anomalies from MERRA Water Cycle Variables during 1979-2013 over 80°W, 35°N

881





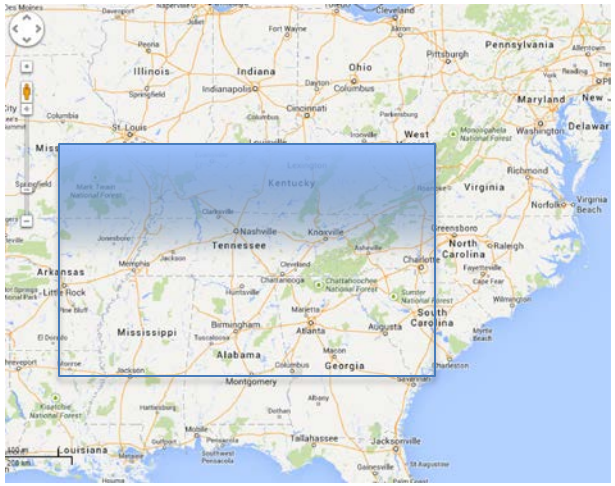
mm/day

Year

Time Series and Trend of Annual Mean, Dry Extreme and Wet Extreme Anomalies from MERRA Water Cycle Variables during 1979-2013 over 92°W-80°W, 33°N-38°N

–0.01061

–0.01061



3

0.01913

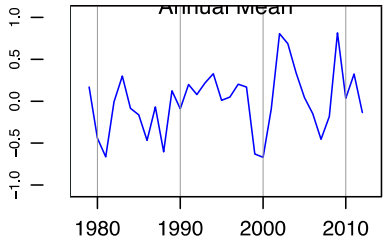
0.01604

–0.00000

–0.00081

–0.00004

mm/day



Year

Time Series and Trend of Annual Mean, Dry Extreme and Wet Extreme Anomalies from MERRA Water Cycle Variables during 1979-2013 over CONUS

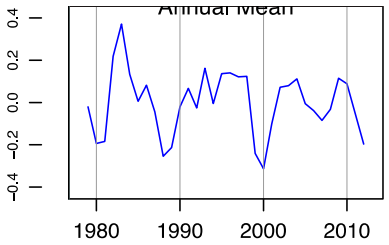
−0.00855

−0.00219

0.00321

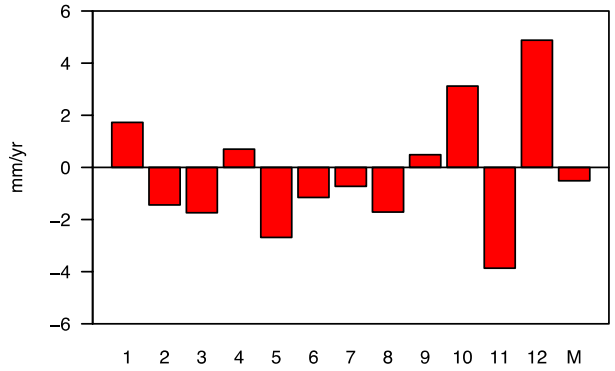
006

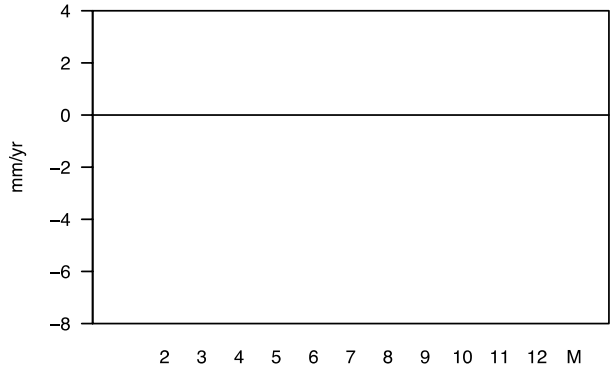
mm/day



Year

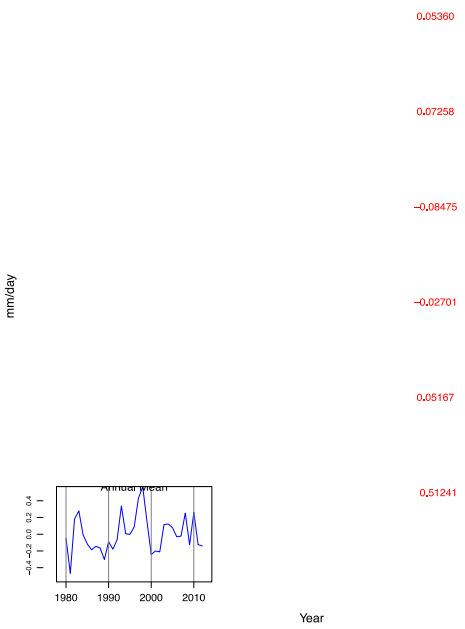
Trend (mm/year) of Monthly Mean MERRA Water Cycle Variables during 1979-2013 over CONUS



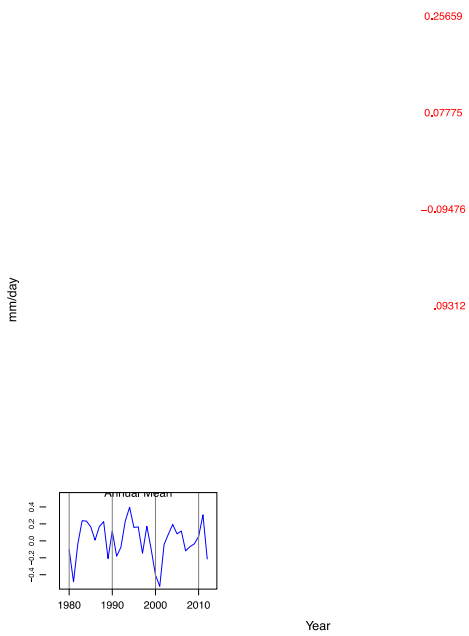


Time Series and Trend of Seasonal Mean, Dry Extreme and Wet Extreme Anomalies from MERRA Water Cycle Variables during 1979-2013 over CONUS

DJF



JJA

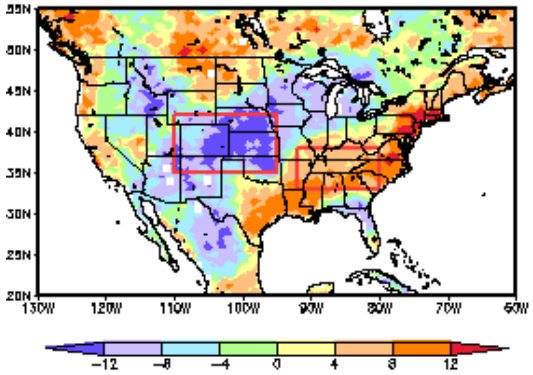


MAM

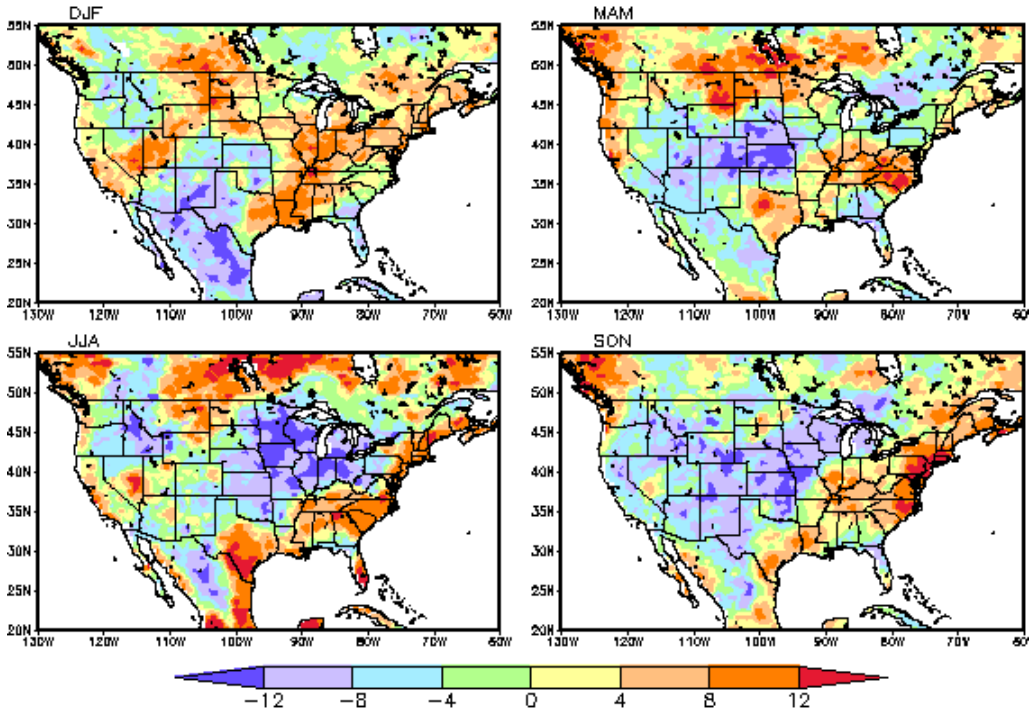
SON

Composite Indicators

Consistency of trend among annual mean, dry extreme and wet extreme anomalies from 6 MERRA water cycle variables during 1979-2013. Right figure shows the sum of number of positive or negative trends among all 18 trends.

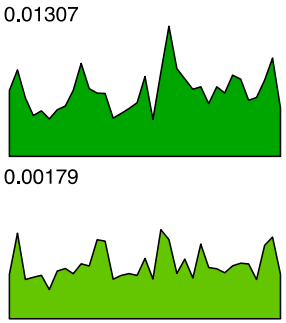


Same as above figure but for 4 different seasons.

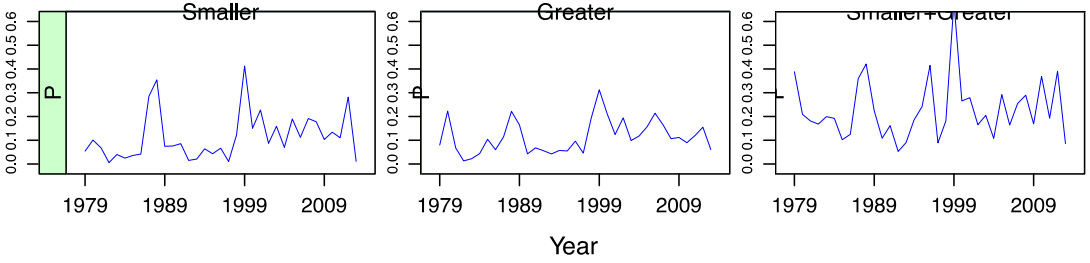


Consistency varies for different regions and seasons with east coast and central region showing robust high consistency in upward and downward trend, respectively.

Percentage of the US with Smaller-Than-Dry-Extreme and Greater-Than-Wet-Extreme Proportion for MERRA Water Cycle Variables during 1979-2013 over CONUS



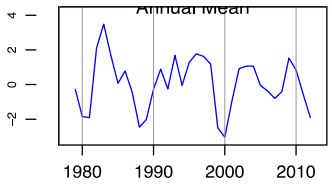
- Except E and dS/dt, percentages of Smaller-Than-Dry-Extreme proportion from other 4 variables show positive trends
- Trends in percentage of Greater-Than-Wet-Extreme proportion appear to be positive except in dS/dt, which is also consistent with the sum of two trends



Normalized Time Series of Annual Mean, Dry Extreme and Wet Extreme Anomalies with Their Corresponding Trends from 6 MERRA Water Cycle Variables during 1979-2013 over CONUS

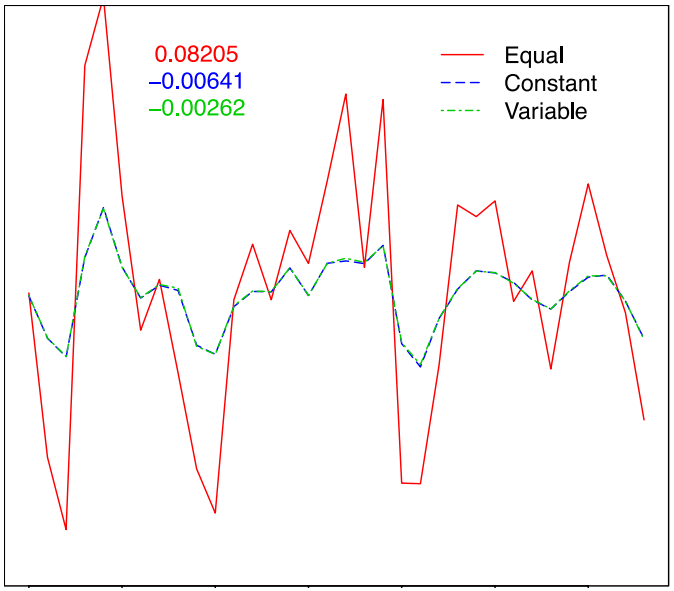
0.01137

993



Year

Sum of 18 Normalized Time Series based on 3 Different Weightings



Red line: each variable has the same weight
Blue line: weights are derived from climatology mean
Green line: weights are from annual mean
Numbers: trend corresponding to line with same color

- Sum with equal weights shows positive trend
- Weights based on climatology mean and annual mean produce comparable negative trends

Conclusions

Initial WCI indicators developed
Scalability tested
Composites created

Future work

Application to other datasets

Predictions: Reanalysis & CMIP5
Observations: Precipitation, GRACE, NVAP, etc.

Validation

Drought monitor, etc.

Interactive visualization