

# The Regional Kendall Test for Trend

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# Seasonal Kendall test for trend

- Most popular trend test in environmental studies
- Developed by Hirsch, Smith and Slack at the USGS in the 1980s
- Now used throughout the world
- Used for many media
- Software available from USGS since 1980s

# Seasonal Kendall test for trend

- Nonparametric test
- Detects monotonic trends, not just linear
- Provides a measure of overall slope (rate of change)
- Conducts trend test within each season, then combines to form one overall test

# Regional Trends ?

- Spatial differences may be of more interest than seasonal differences, especially for ground water or other media without seasonal sampling
- Would like an overall test of whether trends occur across an entire region composed of multiple sampling sites
- A formal test in addition to visual “up and down arrows” at multiple sites on a map

# The Regional Kendall test

- Substitute location for season and run the Seasonal Kendall test
- Trend is tested at each location, then tests combined to look for a consistent regional trend
- Trends in different directions at different sites will cancel each other out, leading to a conclusion of no consistent regional trend

# The Regional Kendall test

- Assumes similar amounts of data at each location
- Nonparametric
- Provides a slope estimate at each site, and one overall for the region
- Blatant knockoff of the Seasonal Kendall test!

# Example

Trends in snowpack chemistry during 1993-2004 in  
the Rocky Mountain region, USA

George Ingersoll

USGS

# Field Methods

## Full snowpack sample

- Sites selected free of local activity
- Temp & physical characteristics measured
- Collected before annual melt begins
- Preserved frozen until analyzed for major ions, pH, SC, DOC, mercury, isotopes Sulfur & Nitrogen

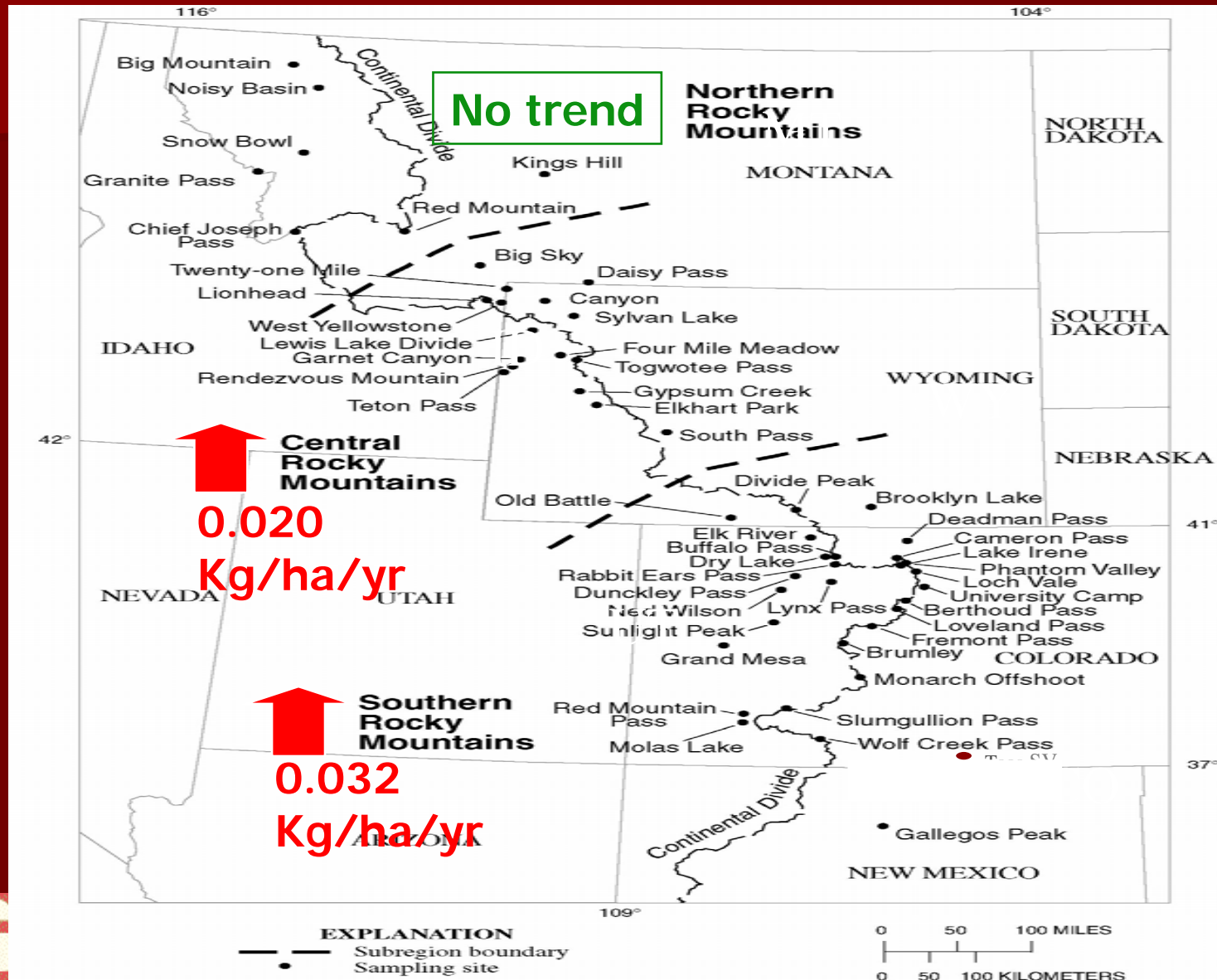




# Statistical methods

- Computed the Regional Kendall test in each of 3 sub-regions with different storm patterns and airsheds
- 54 sites in 3 sub-regions, 12 years
- $\text{NH}_4$ ,  $\text{NO}_3$ ,  $\text{SO}_4$ , snow depth

# Sub-regions evaluated for long-term trends in NO<sub>3</sub>

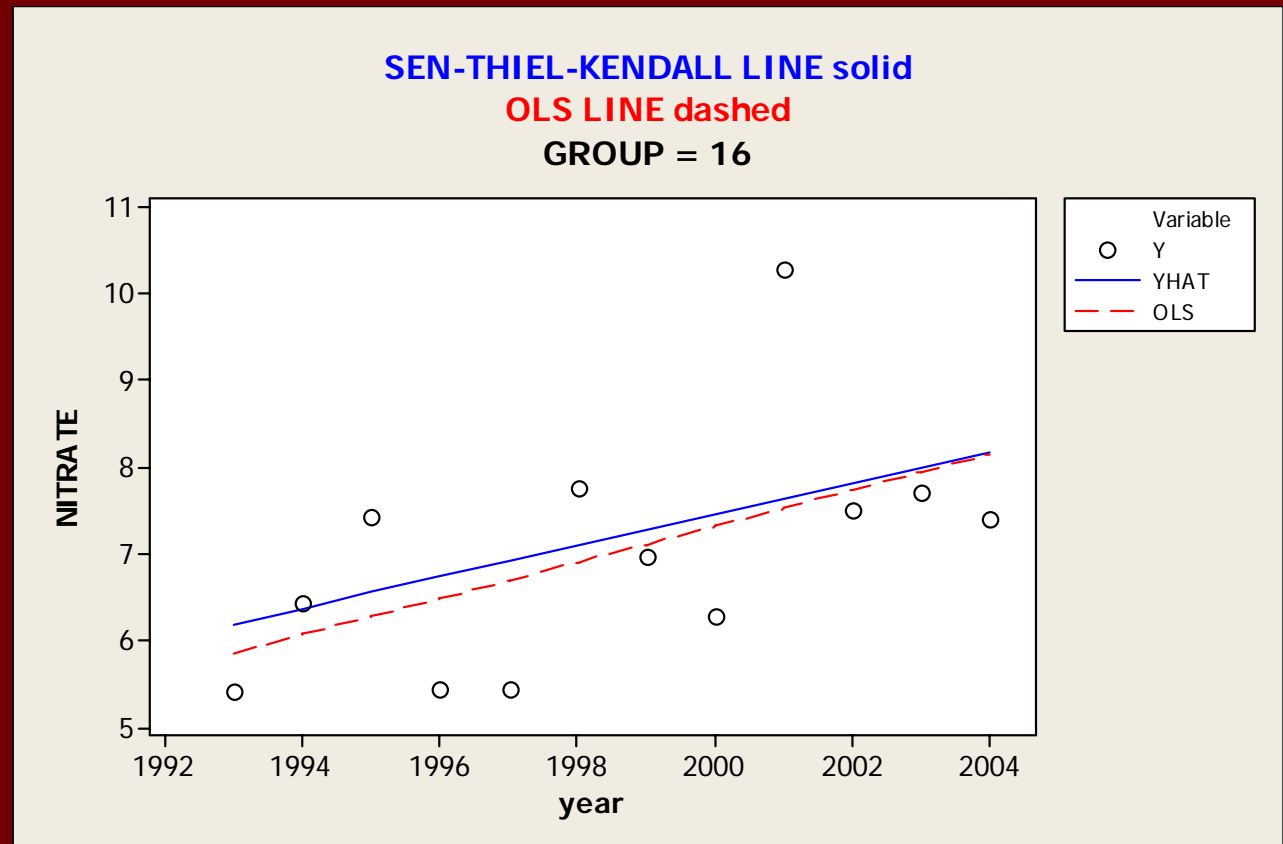


# Nitrate in snow of the Central Rocky Mountains

- 17 measurement locations

Site 16

- 3 of the 17 showed significant increases in NO<sub>3</sub> concentrations

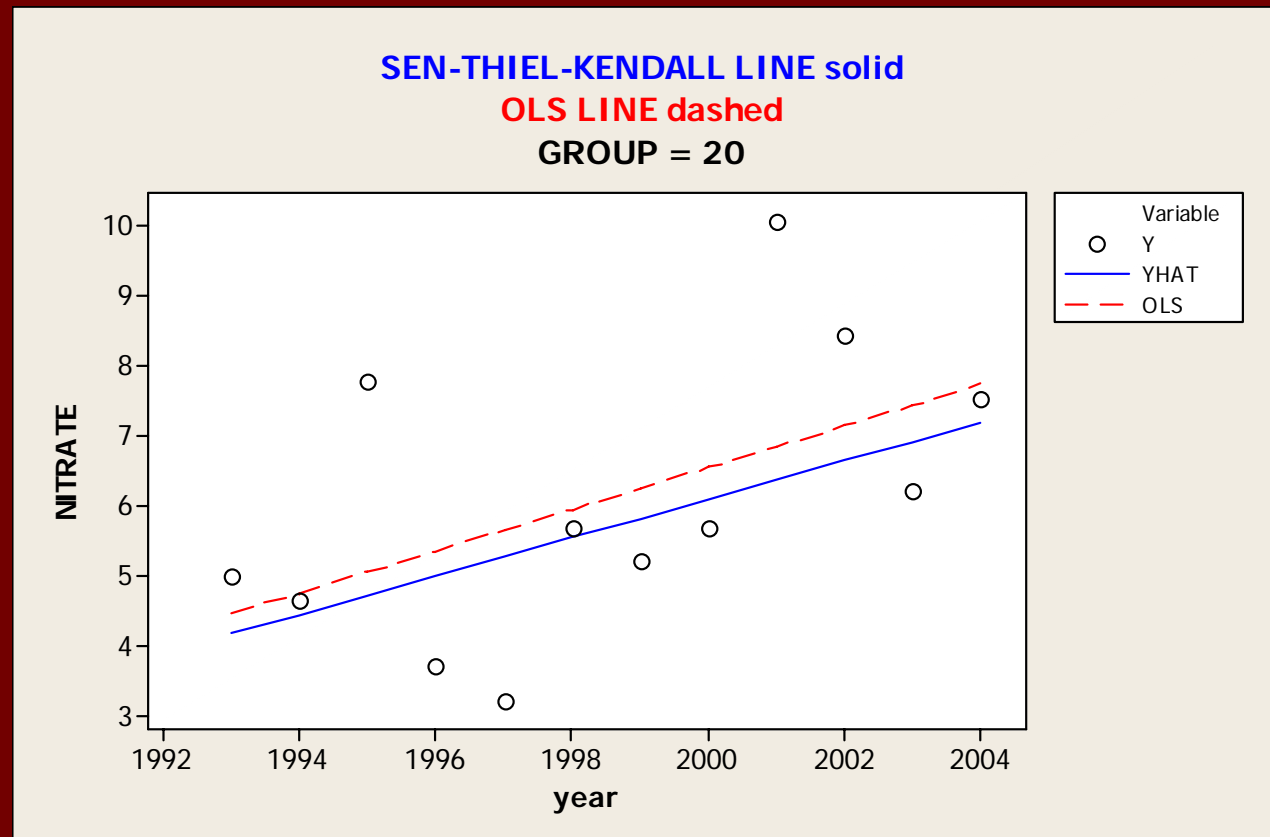


# Nitrate in snow of the Central Rocky Mountains

■ 17 measurement locations

Site 20

■ 3 of the 17 showed significant increases in NO<sub>3</sub> concentrations

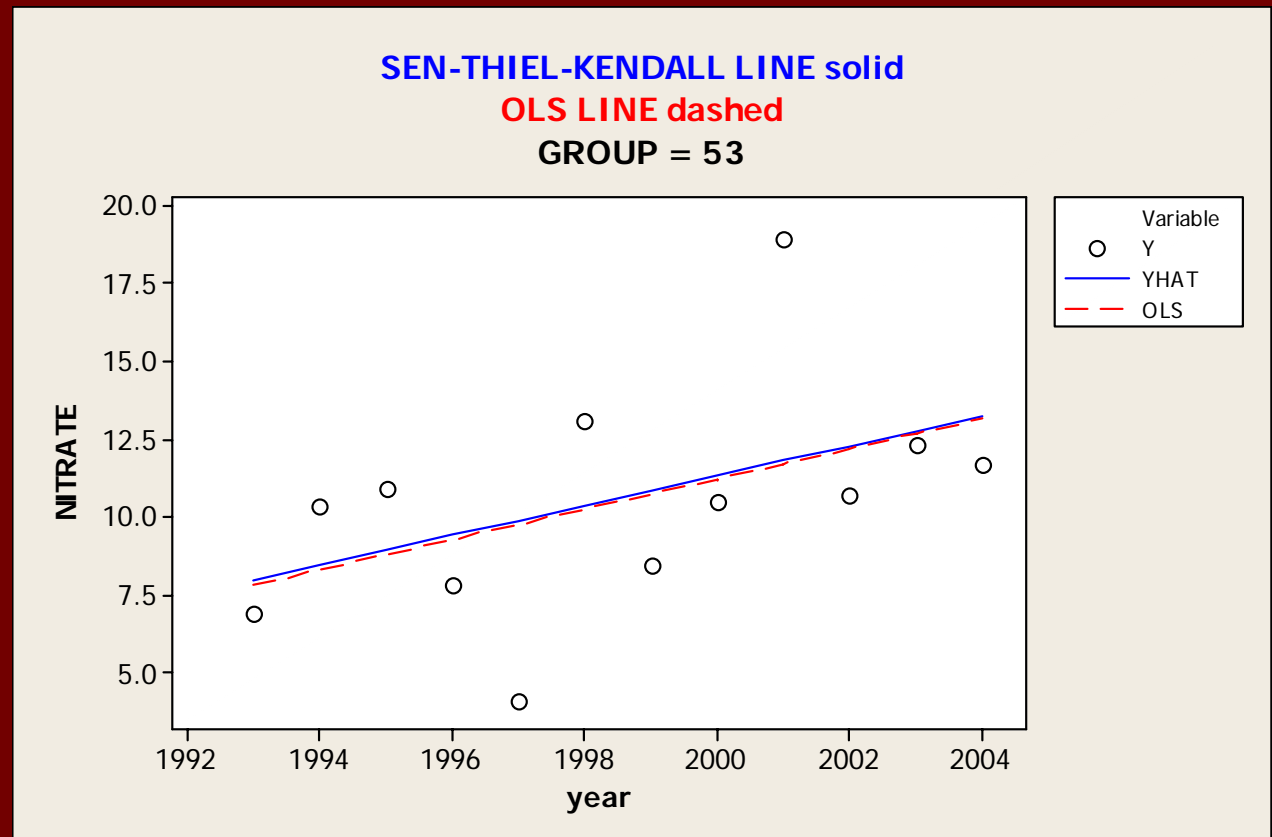


# Nitrate in snow of the Central Rocky Mountains

■ 17 measurement locations

Site 53

■ 3 of the 17 showed significant increases in NO<sub>3</sub> concentrations

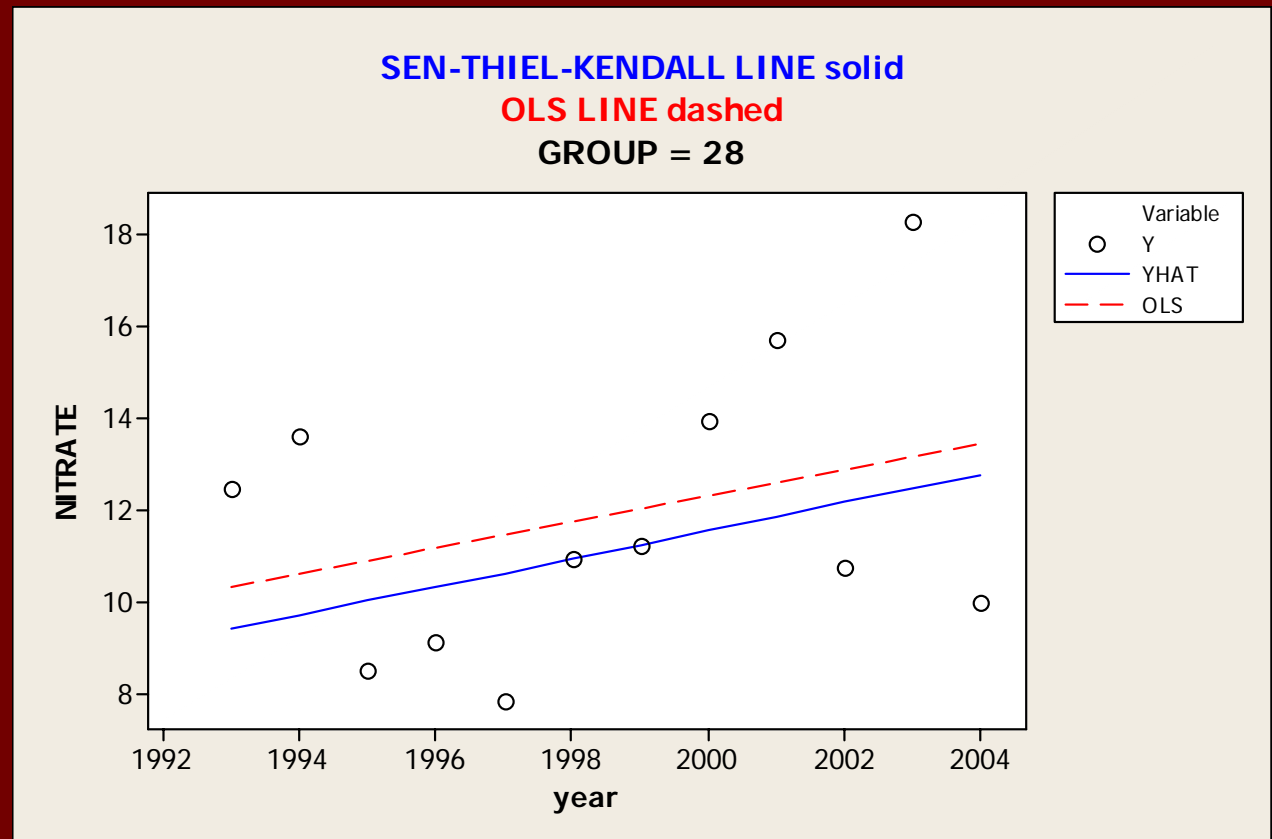


# Nitrate in snow of the Central Rocky Mountains

■ 17 measurement locations

Site 28

■ 14 of the 17 showed  
insignificant  
trends in NO<sub>3</sub>,  
but most were  
still increases

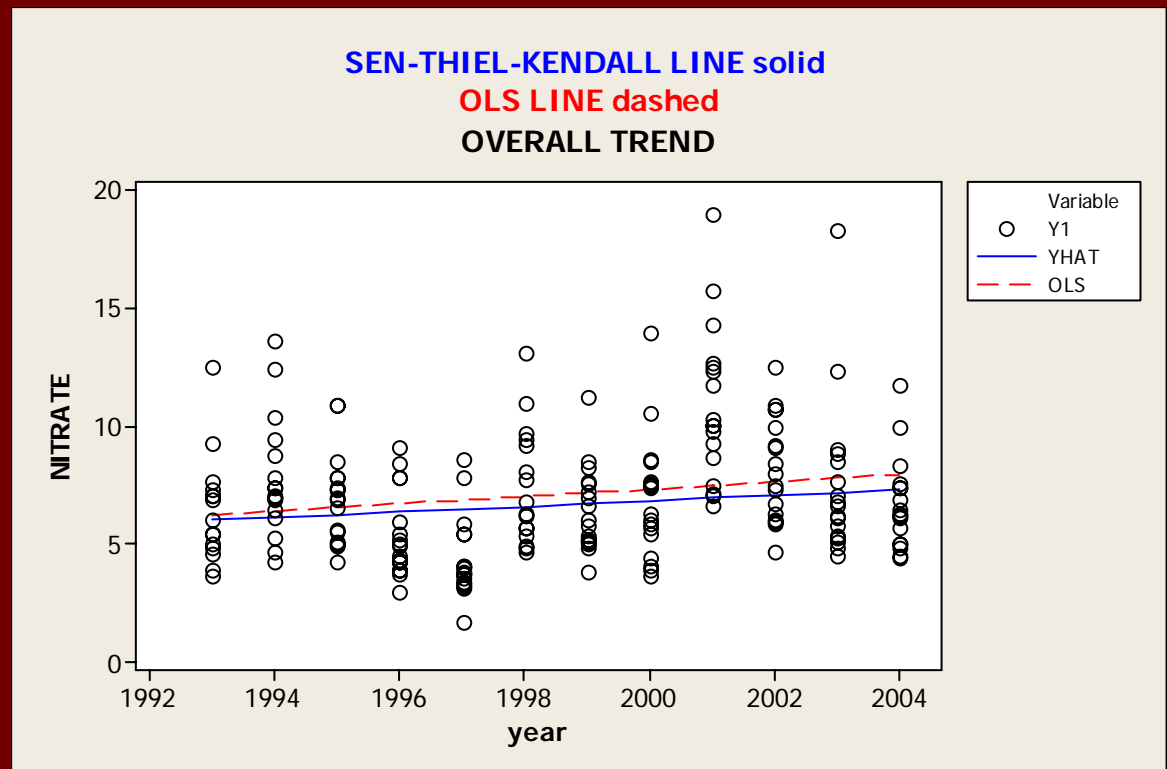


# Nitrate in snow of the Central Rocky Mountains

- Significant trends and predominance of increases (even when not significant) are combined and evaluated by the Regional Kendall test

■ Overall  
p-value is  
0.004

Regional trend



# How the Regional Kendall test works

At each location, the test statistic

$$S_{loc} = \# \text{ pluses} - \# \text{ minuses}$$

for all comparisons between measurements

Test statistic for regional trend:

$$S_{RK} = \text{Sum } [S_{loc}]$$



# How the Regional Kendall test works

- Scale  $S_{RK}$  by dividing by its standard error. The resulting ratio can be fit by a normal distribution
- Look up p-value
- Identical process to the Seasonal Kendall test

# Adjunct methods to the Regional Kendall test

- Van Belle and Hughes (1984) proposed a test for heterogeneity of trend – are the trends at individual sites going in the same direction?
- Can also use with collections of sites to test for differences between sub-regional trends (Northern vs. Central vs. Southern Rocky Mountains)

# Availability of Code

USGS Scientific Investigations Report (SIR) 2005 -  
5275 by Helsel, Mueller and Slack

.exe file runs using DOS commands within  
Windows

Jim Slack's original code was refurbished to run the  
Regional Kendall test, as well as simple Kendall's  
tau correlation.

Report and software available online at

<http://pubs.er.usgs.gov/usgspubs/sir/sir20055275>