# Title: Can soil respiration measured at annual mean temperature represents actual annual soil respiration

# Rs\_MAT – Soil respiration measured at mean soil temperature (air temperature) moment

**Rs\_Annual** – Soil respiration measured across a whole year

# 1. Background

# Why it is important

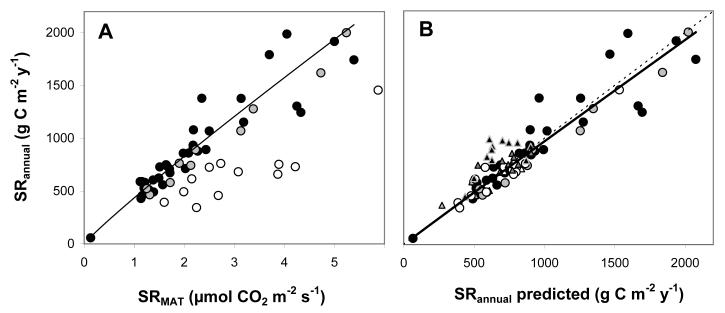
# We used this approach a lot in daily and monthly time scale

**In annual time scale, however, it may not work (i.e., cannot directly use Rs\_MAT stand for Rs\_Annual)**

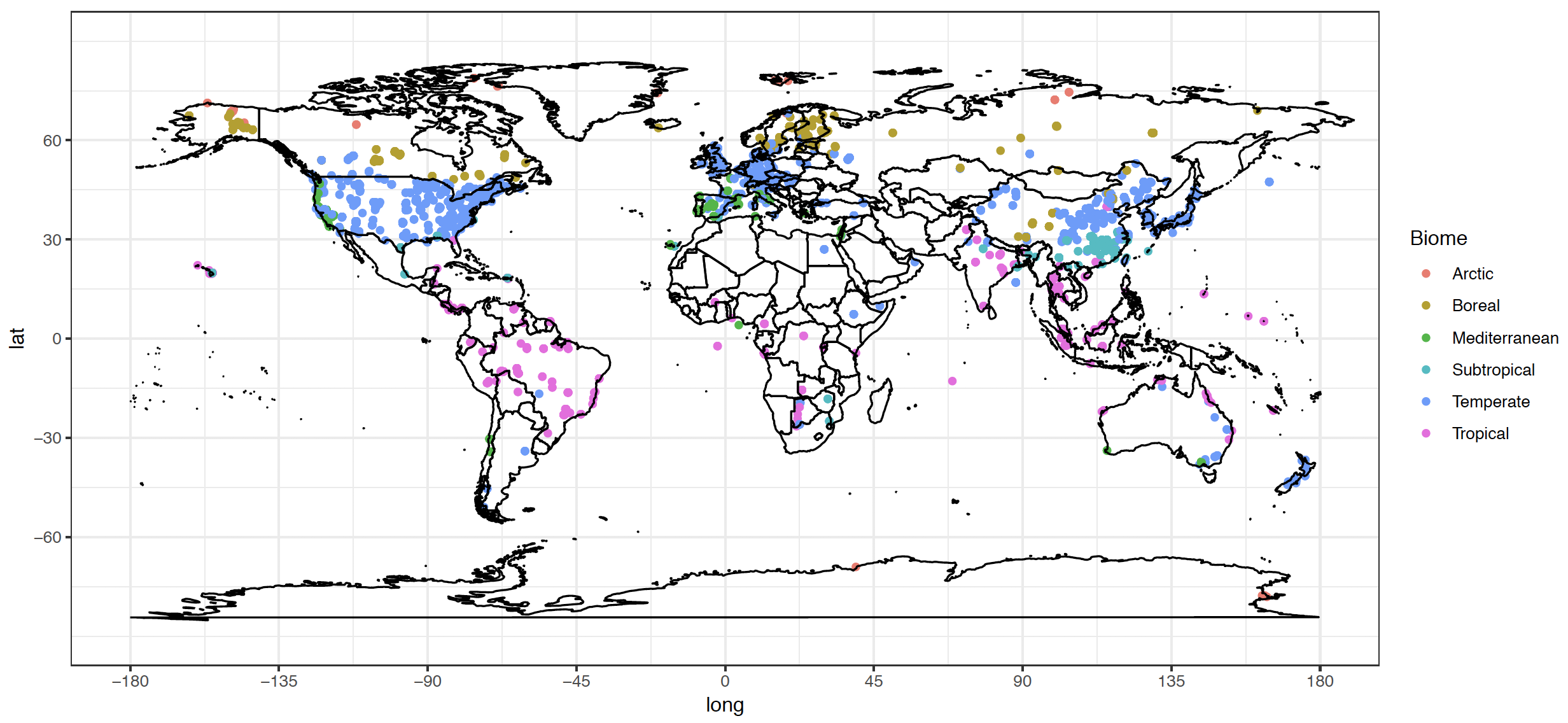
# Rs measured at diurnal soil temperature

# . The spatial destribution of global Rs sites

* We have much more measured Rs from the middle latitude region
* It is difficult to measure soil respiration all year around in the cold region
* Developed contries most located at Middle latitude region, thus recieved more funds to support the Rs measurements



**Bahn’s approach** [Bahn et al. (2010) Biogeosciences], Rs\_annual = 455.8 \* Rs\_MAT^1.0054 (R^2 = 0.94, p<0.001)



Global spatial destribution of soil repiration sites

# 2. The object of this analysis are

* Test Bahn (2010) approach using srdb\_v4, when it works, and when it not works?
* If not, why and what is the mechanism?
* Update the model based on more data from srdb\_v4

# 3. Methods

**Data**

* SRDB\_V4 – Rs\_Annual
* Annual mean soil temperature (read from papers or calculated with a simple assumption)
* Relationship between Rs and soil temperature (SRDB\_V4)
* 823 records from 253 studies

**Rs\_MAT calculation and statistics analysis**

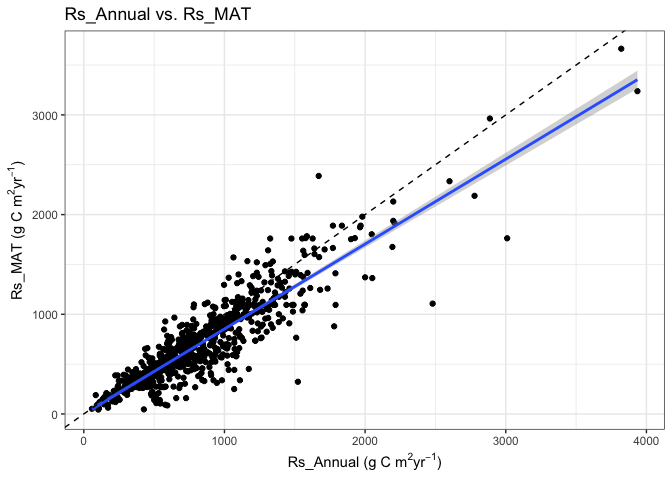
* Ts\_MAT 🡪 Rs ~ Ts relationship 🡪 Rs\_MAT
* **Rs\_annual =** **455.8 \* Rs\_MAT^1.0054** 🡪 **Rs\_annual\_bahn**

**Update Bahn’s model**

* Srdb\_v4 🡪 Bahn’s model (**Rs\_annual = a \* Rs\_MAT^b**) 🡪 new parameters

# 4. Results

## 4.1 Test the relationship between Rs\_annual and Rs\_MAT



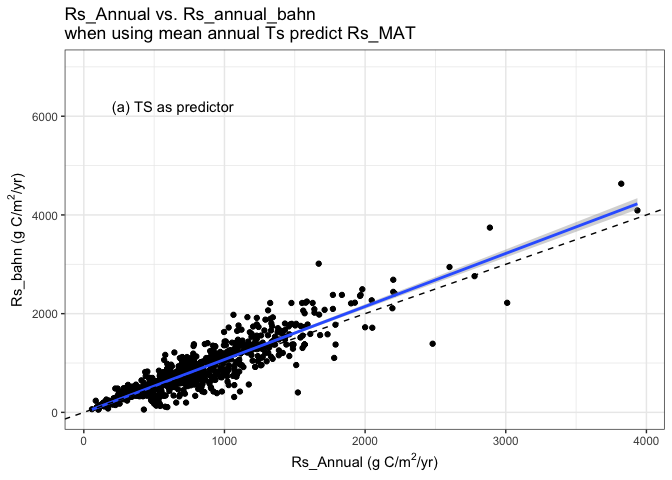
## lm(formula = Rs\_TAIR ~ Rs\_annual, data = sdata)  
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 0.64266 13.67584 0.047 0.963   
## Rs\_annual 0.85184 0.01466 58.126 <2e-16 \*\*\*

## Residual standard error: 185.1 on 821 degrees of freedom  
## Multiple R-squared: 0.8045, Adjusted R-squared: 0.8043   
## F-statistic: 3379 on 1 and 821 DF, p-value: < 2.2e-16

## [1] "test intercept=0 and slope=1"  
## [1] "p\_intercept = 0.9625, p\_slope = 0"

## 

## 4.2 Using Bahn(2010) model to predict Rs\_annual\_bahn



## Wed Apr 3 11:03:11 2019 -------------------  
## Call:  
## lm(formula = temp ~ Rs\_annual, data = sdata)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -1270.56 -106.41 19.13 116.92 1221.77   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -4.35814 17.24982 -0.253 0.801   
## Rs\_annual 1.07472 0.01849 58.140 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 233.5 on 821 degrees of freedom  
## Multiple R-squared: 0.8046, Adjusted R-squared: 0.8043   
## F-statistic: 3380 on 1 and 821 DF, p-value: < 2.2e-16  
##   
## 3 11:03:11 2019 Test H0 of intercept=0: p-value = 0.800603  
## Wed Apr 3 11:03:11 2019 Test H0 of slope=1: p-value = 5.798985e-05

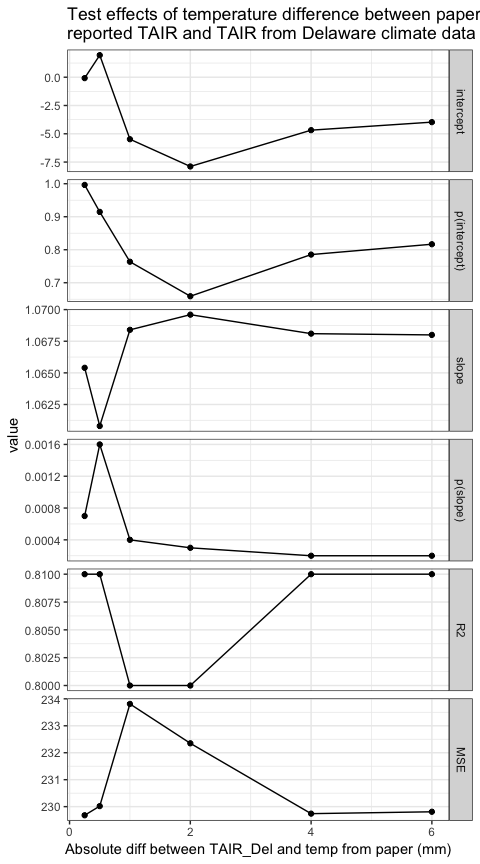
## [1] p\_intercept = 0.800603

## [1] p\_slope = 5.798985e-05

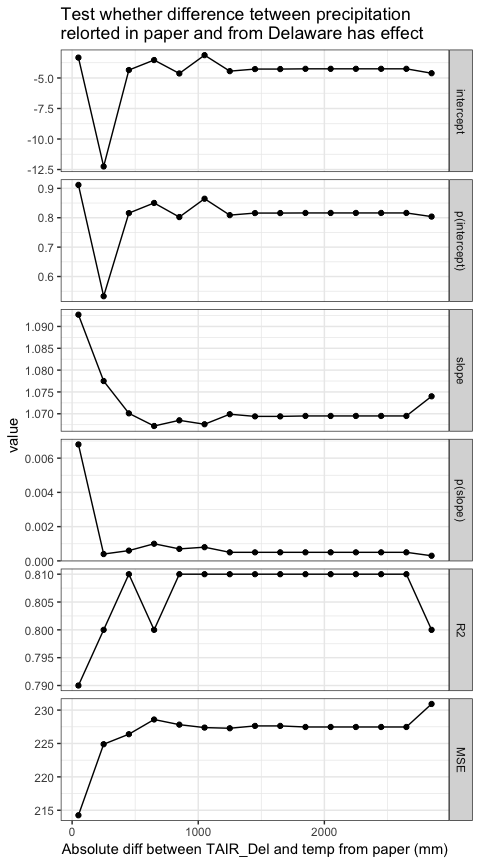
## 4.3 Test when not works and why

## 4.3.1 Effect of maximum allowed divergence between global climate data set and site-specific air temperature

* TAIR\_dev = abs( MAT\_Del - MAT )
* Set up a threshold (6, 4, 2, 1, 0.5, 0.25), any records with TAIR\_dev > the threshold will be throw away
* Test the rest

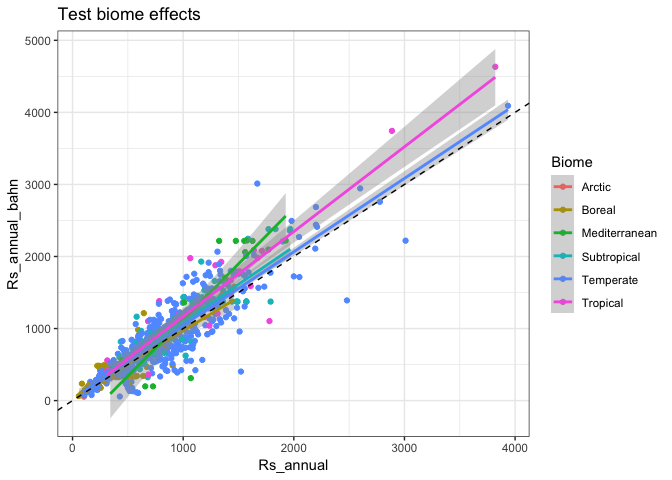


## 4.3.2 Effect of maximum allowed divergence between annual precipitation from paper and Delaware climate data



### 4.3.3 Biome effect

##   
## Call:  
## lm(formula = Rs\_annual\_bahn ~ Rs\_annual \* Biome, data = srdb)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -1174.64 -104.79 8.19 123.61 1283.73   
##   
## Coefficients: (1 not defined because of singularities)  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -66.80877 227.89726 -0.293 0.76948   
## Rs\_annual 1.17678 0.05508 21.366 < 2e-16 \*\*\*  
## BiomeBoreal 113.46654 234.16931 0.485 0.62813   
## BiomeMediterranean -369.22121 269.23223 -1.371 0.17063   
## BiomeSubtropical 120.80677 235.67500 0.513 0.60837   
## BiomeTemperate 93.10098 228.83632 0.407 0.68423   
## BiomeTropical 58.62423 237.83119 0.246 0.80536   
## Rs\_annual:BiomeBoreal -0.25204 0.11340 -2.223 0.02652 \*   
## Rs\_annual:BiomeMediterranean 0.37897 0.12742 2.974 0.00302 \*\*   
## Rs\_annual:BiomeSubtropical -0.13619 0.08153 -1.670 0.09522 .   
## Rs\_annual:BiomeTemperate -0.15752 0.05954 -2.646 0.00831 \*\*   
## Rs\_annual:BiomeTropical NA NA NA NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 227.8 on 812 degrees of freedom  
## Multiple R-squared: 0.816, Adjusted R-squared: 0.8137   
## F-statistic: 360.1 on 10 and 812 DF, p-value: < 2.2e-16



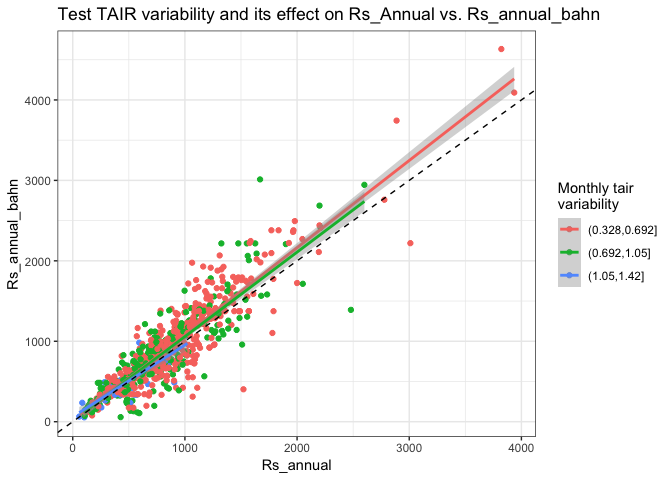
## Biome R2\_mv Slope\_mv p\_slope\_mv intercept\_mv  
## Rs\_annual Boreal 0.80 1.08 0.0001 -3.74  
## Rs\_annual1 Mediterranean 0.81 1.06 0.0024 7.49  
## Rs\_annual2 Subtropical 0.80 1.08 0.0002 -9.15  
## Rs\_annual3 Temperate 0.86 1.17 0.0000 -48.17  
## Rs\_annual4 Tropical 0.79 1.05 0.0082 8.83  
## p\_intercept\_mv MSE\_mv  
## Rs\_annual 0.8459 239.73  
## Rs\_annual1 0.6586 226.82  
## Rs\_annual2 0.6182 238.37  
## Rs\_annual3 0.0999 228.03  
## Rs\_annual4 0.6182 228.82

## 4.3.4 TAIR and precipitation variability affect?

## Wed Apr 3 11:03:27 2019 -------------------  
## Wed Apr 3 11:03:27 2019 How does climate variability affect this relationship?  
##   
## Call:  
## lm(formula = Rs\_annual\_bahn ~ Rs\_annual \* TAIR\_SD2, data = sdata)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -1241.54 -105.63 18.66 116.66 1250.75   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -5.99228 24.56567 -0.244 0.807   
## Rs\_annual 1.08443 0.02403 45.119 <2e-16 \*\*\*  
## TAIR\_SD2(0.692,1.05] 13.72567 37.30563 0.368 0.713   
## TAIR\_SD2(1.05,1.42] 66.74171 75.97634 0.878 0.380   
## Rs\_annual:TAIR\_SD2(0.692,1.05] -0.03431 0.04077 -0.841 0.400   
## Rs\_annual:TAIR\_SD2(1.05,1.42] -0.19145 0.13718 -1.396 0.163   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 233.5 on 817 degrees of freedom  
## Multiple R-squared: 0.8055, Adjusted R-squared: 0.8043   
## F-statistic: 676.5 on 5 and 817 DF, p-value: < 2.2e-16

## Wed Apr 3 11:03:27 2019 Saving outputs/4.2.6\_var\_effect\_tair.pdf

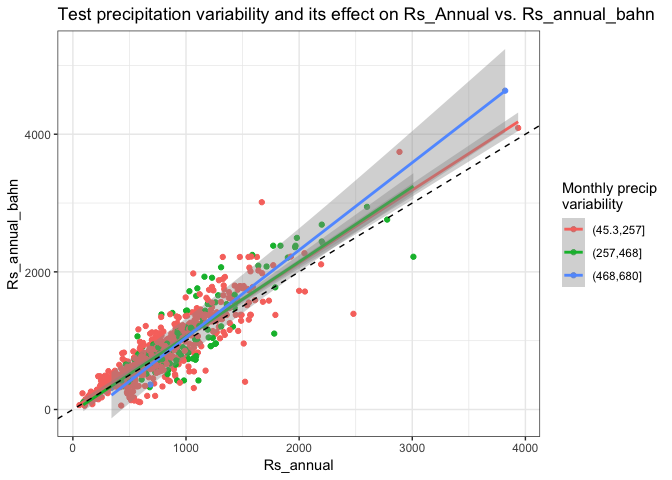
## Saving 7 x 5 in image



##   
## Call:  
## lm(formula = Rs\_annual\_bahn ~ Rs\_annual \* PRECIP\_SD2, data = sdata)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -1248.00 -106.68 15.86 116.29 1232.15   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 10.38548 19.46686 0.533 0.5938   
## Rs\_annual 1.05967 0.02232 47.467 <2e-16 \*\*\*  
## PRECIP\_SD2(257,468] -42.31196 48.89676 -0.865 0.3871   
## PRECIP\_SD2(468,680] -235.91911 147.04492 -1.604 0.1090   
## Rs\_annual:PRECIP\_SD2(257,468] 0.02917 0.04616 0.632 0.5277   
## Rs\_annual:PRECIP\_SD2(468,680] 0.21125 0.08361 2.527 0.0117 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 233 on 817 degrees of freedom  
## Multiple R-squared: 0.8063, Adjusted R-squared: 0.8051   
## F-statistic: 680.1 on 5 and 817 DF, p-value: < 2.2e-16

## Wed Apr 3 11:03:27 2019 Saving outputs/4.2.6\_var\_effect\_precip.pdf

## Saving 7 x 5 in image



## 4.3.5 Drought affect

Call:

lm(formula = Rs\_annual\_bahn ~ Rs\_annual \* SPI2, data = sdata)

Residuals:

Min 1Q Median 3Q Max

-1207.66 -111.58 15.77 116.48 1258.29

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 1.99947 48.51641 0.041 0.96714

Rs\_annual 1.18864 0.04748 25.035 < 2e-16 \*\*\*

SPI2(-1,1] -2.16527 52.46724 -0.041 0.96709

SPI2(1,3] 11.52099 65.92498 0.175 0.86131

SPI2(3,5] 265.23165 426.02081 0.623 0.53374

Rs\_annual:SPI2(-1,1] -0.14157 0.05242 -2.701 0.00706 \*\*

Rs\_annual:SPI2(1,3] -0.14650 0.06486 -2.259 0.02416 \*

Rs\_annual:SPI2(3,5] -0.73067 0.96525 -0.757 0.44928

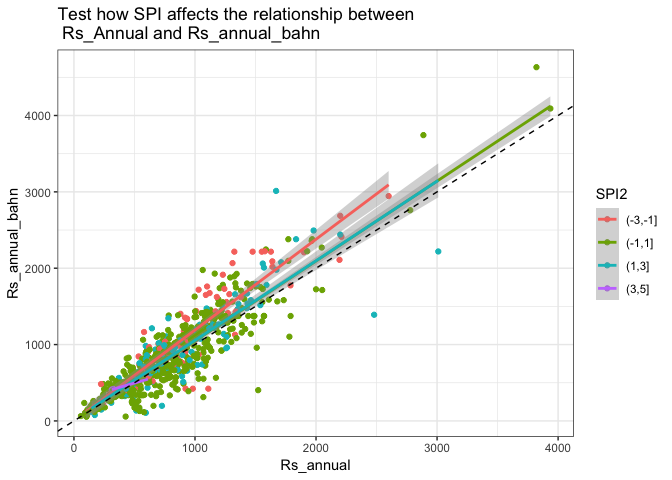
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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

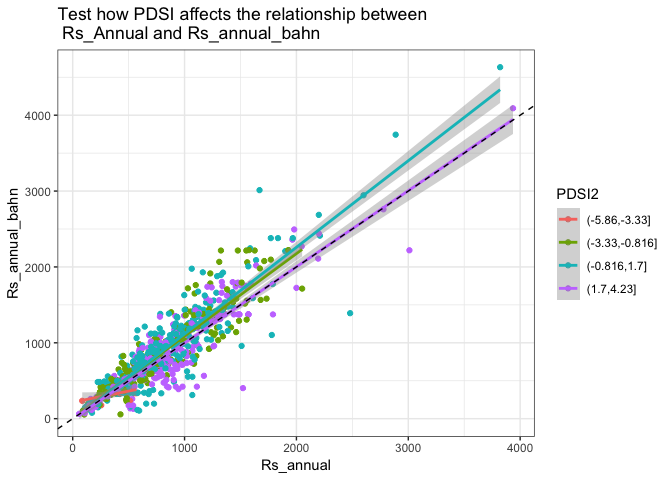
Residual standard error: 229.3 on 815 degrees of freedom

Multiple R-squared: 0.813, Adjusted R-squared: 0.8114

F-statistic: 506.2 on 7 and 815 DF, p-value: < 2.2e-16



## Wed Apr 3 11:03:29 2019 -------------------  
## Wed Apr 3 11:03:29 2019 How does drought affect this relationship? (discrete)  
##   
## Call:  
## lm(formula = Rs\_annual\_bahn ~ Rs\_annual \* PDSI2, data = sdata)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -1416.23 -104.92 16.56 107.65 1129.58   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 216.7363 169.6390 1.278 0.2017   
## Rs\_annual 0.2935 0.4205 0.698 0.4853   
## PDSI2(-3.33,-0.816] -215.3118 173.1452 -1.244 0.2140   
## PDSI2(-0.816,1.7] -239.1508 171.6835 -1.393 0.1640   
## PDSI2(1.7,4.23] -223.4889 172.3152 -1.297 0.1950   
## Rs\_annual:PDSI2(-3.33,-0.816] 0.7939 0.4222 1.880 0.0604 .  
## Rs\_annual:PDSI2(-0.816,1.7] 0.8472 0.4214 2.010 0.0447 \*  
## Rs\_annual:PDSI2(1.7,4.23] 0.7104 0.4215 1.685 0.0923 .  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 228.2 on 815 degrees of freedom  
## Multiple R-squared: 0.8147, Adjusted R-squared: 0.8131   
## F-statistic: 511.7 on 7 and 815 DF, p-value: < 2.2e-16  
##



# 5. Discussion & analysis in the future

* Use Rs\_mat predict Rh?
* Use this approach estimate global Rs
* Think about application
* Update bahn model with more predictors or using regression tree method?