Groundwater Heating in Forested Wetlands: A Pilot Study in the Hoh River Watershed

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The Hoh Tribe

Acknowledgements

- The Hoh Tribe Pacific Coast Salmon Recovery Program
- Northwest Indian Fisheries Commission
- The Hoh Tribe JFE crew & Jerry Baker

Why?

- Hoh Tribe was interested in knowing more about influence of forest practices on small, groundwater fed rearing streams
- Perched saturation in shallow soil horizons on hillslopes is an important subsurface flowpath that contributes water and energy to wetlands and small tributaries used for salmon rearing
- More research on flow dynamics in shallow subsurface flow in forested landscapes, but limited on heat transport to streams

Objectives

- This pilot study examines groundwater heat transport responses to forest management practices in the Hoh River basin

- Primary objectives:
  - Investigate the relationship between forest management practices and groundwater temperature
  - Evaluate the relationship between groundwater temperature and heat transport to streams

Hypotheses

1. H_o 1 (null hypothesis): Groundwater discharge temperatures are not significantly altered by canopy removal at depths equal or greater than 0.5 meters.

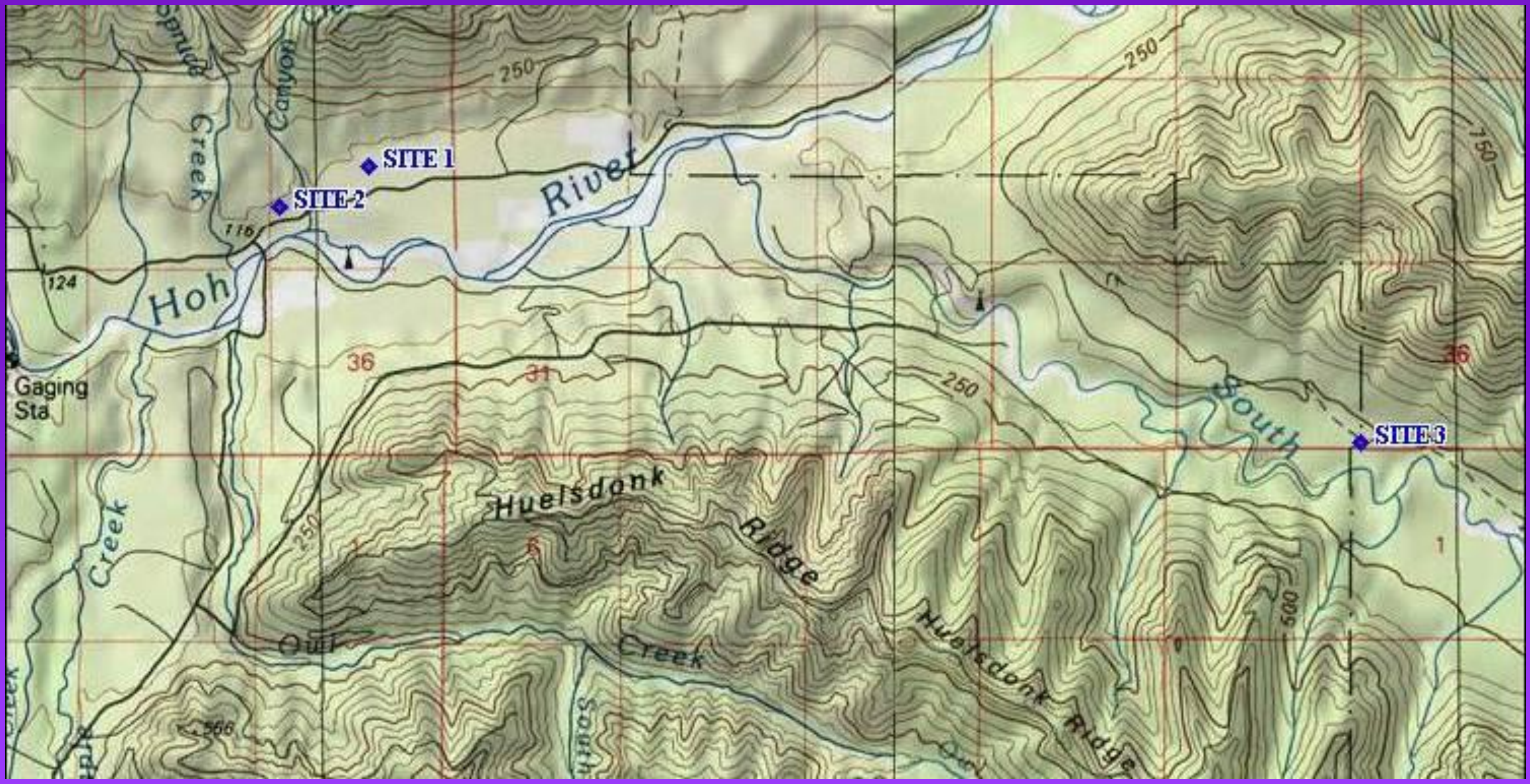
    1. H_a 1 (alternative hypothesis): Groundwater discharge temperatures at depths => 0.5 meters are significantly altered by canopy removal

2. H_o 1: Stream temperature is significantly related to air temperature

    1. H_a:2 (general alternative hypothesis): Stream temperature is significantly related to soil temperature
    2. H_a:3 (general alternative hypothesis): Stream temperature is significantly related to groundwater temperature

Criteria for Sites

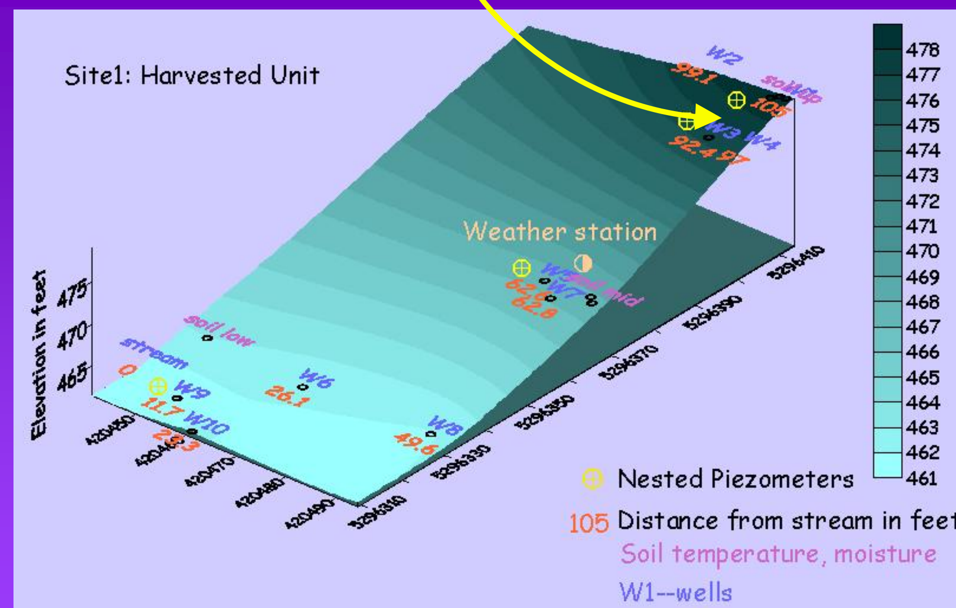
- Similarity in
  - Soils with similar hydrologic characteristics
  - Slope aspect—south to southwest
  - Topography—streams or wetlands on terraces and hillslope
  - Three land covers: stand to be harvested, mature growth similar to site to be harvested, old growth



SITE 1

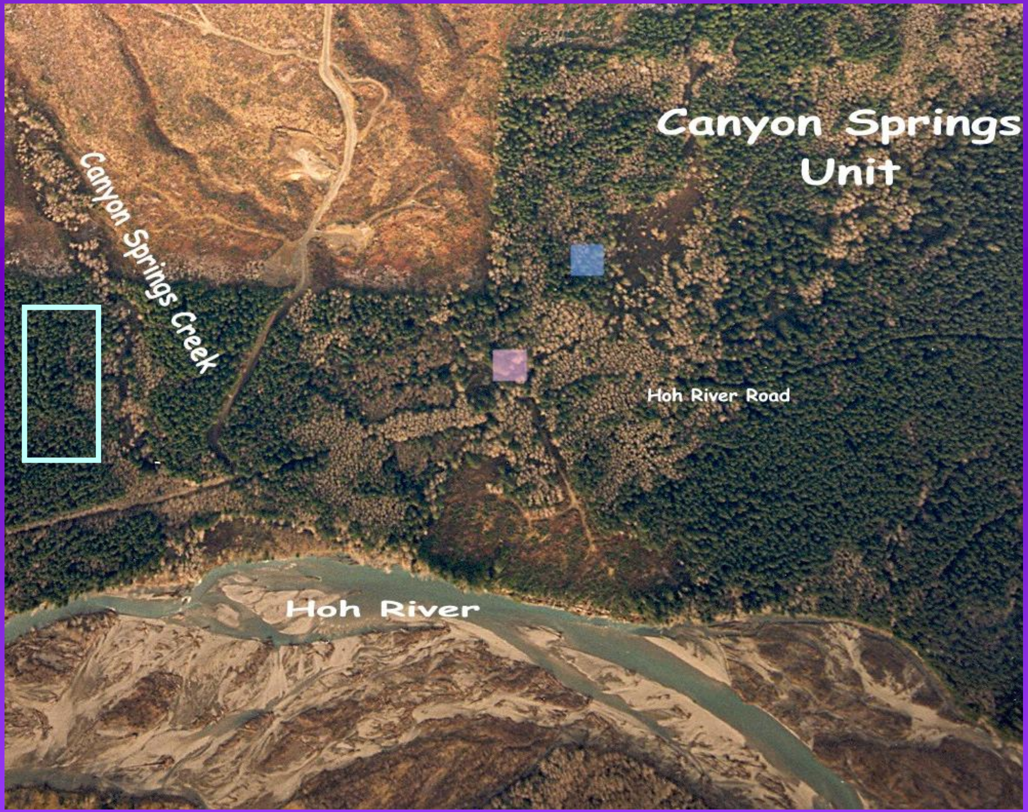
- Mature growth forest harvested in 2001

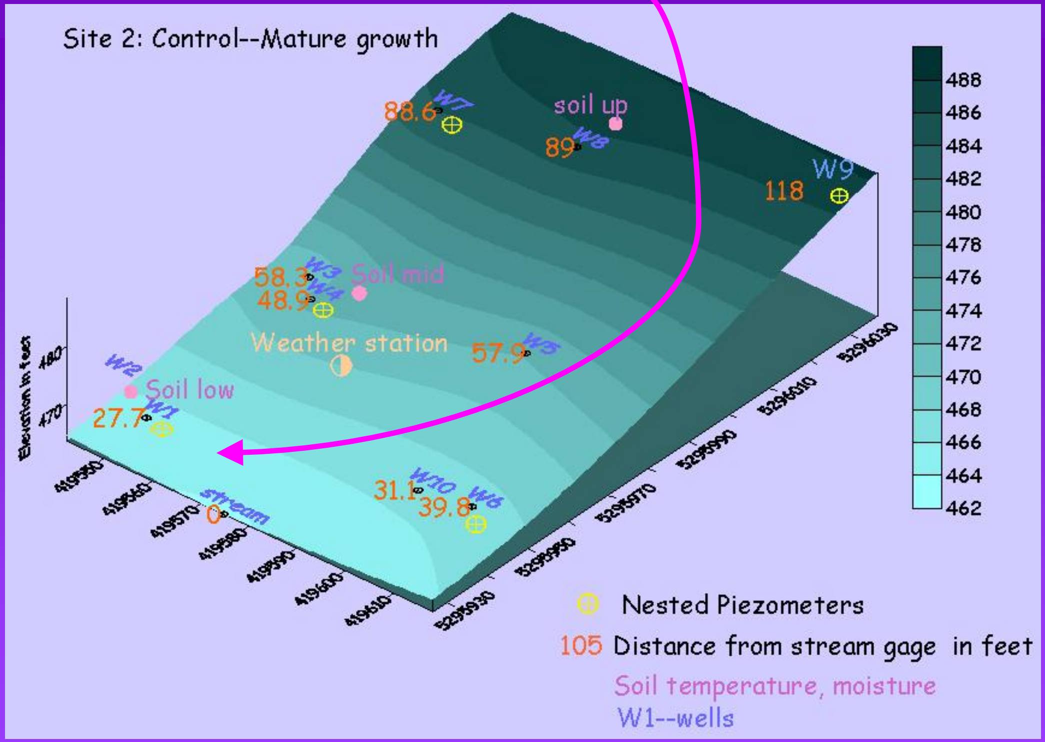
Site 1:
Pre-harvest installation—08/08/ 2001
Post-harvest installation—11/11/2001



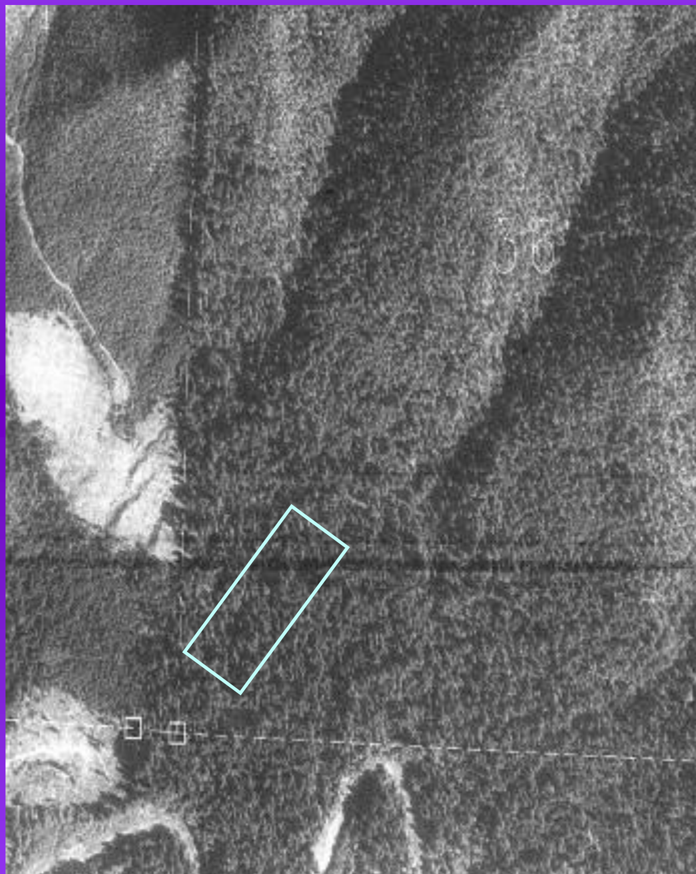
SITE 2: Control

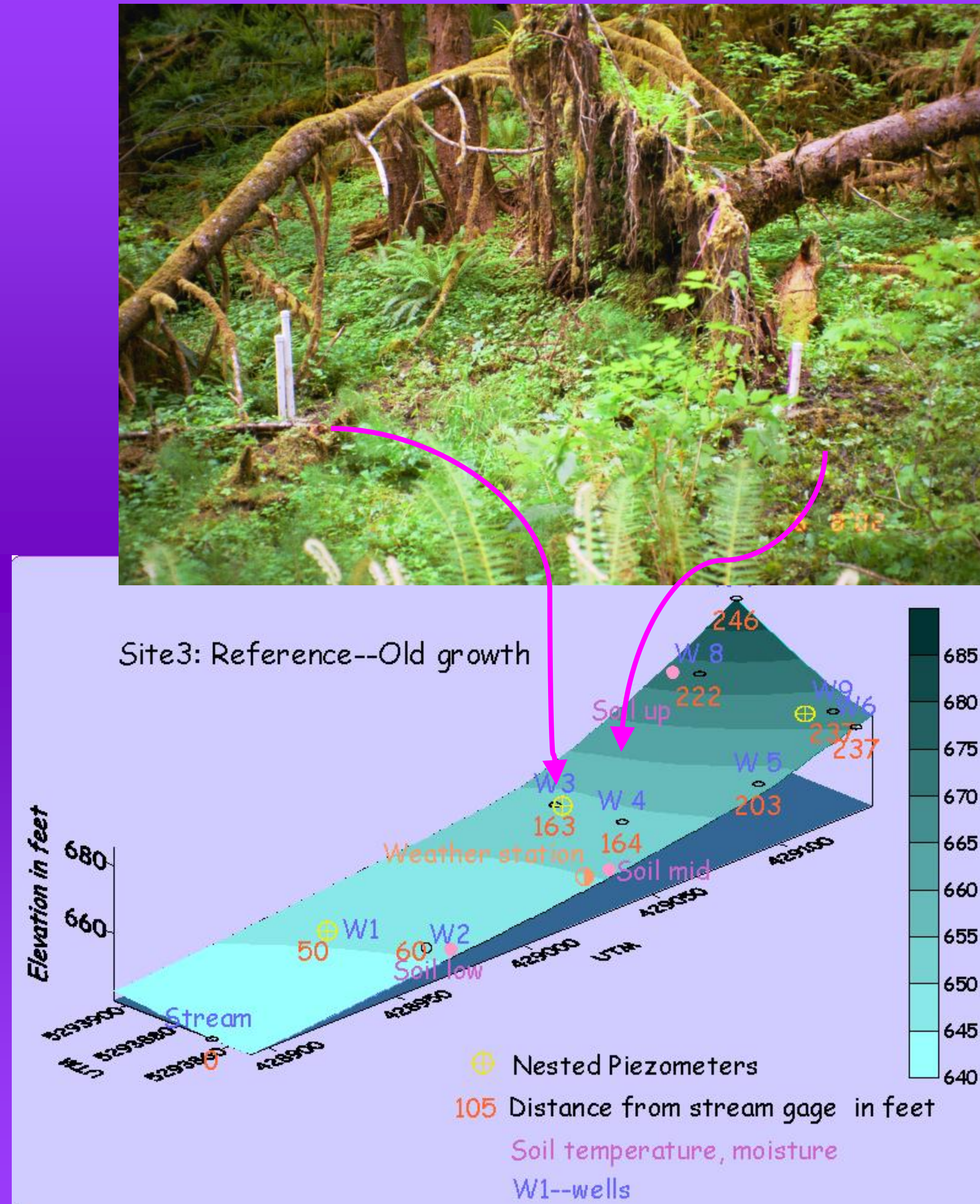
- Mature second growth forest





Site 3: Reference Old Growth Site





Questions

1. Does canopy removal change groundwater temperatures?

2. Do changes in soil and groundwater temperature affect stream temperature?

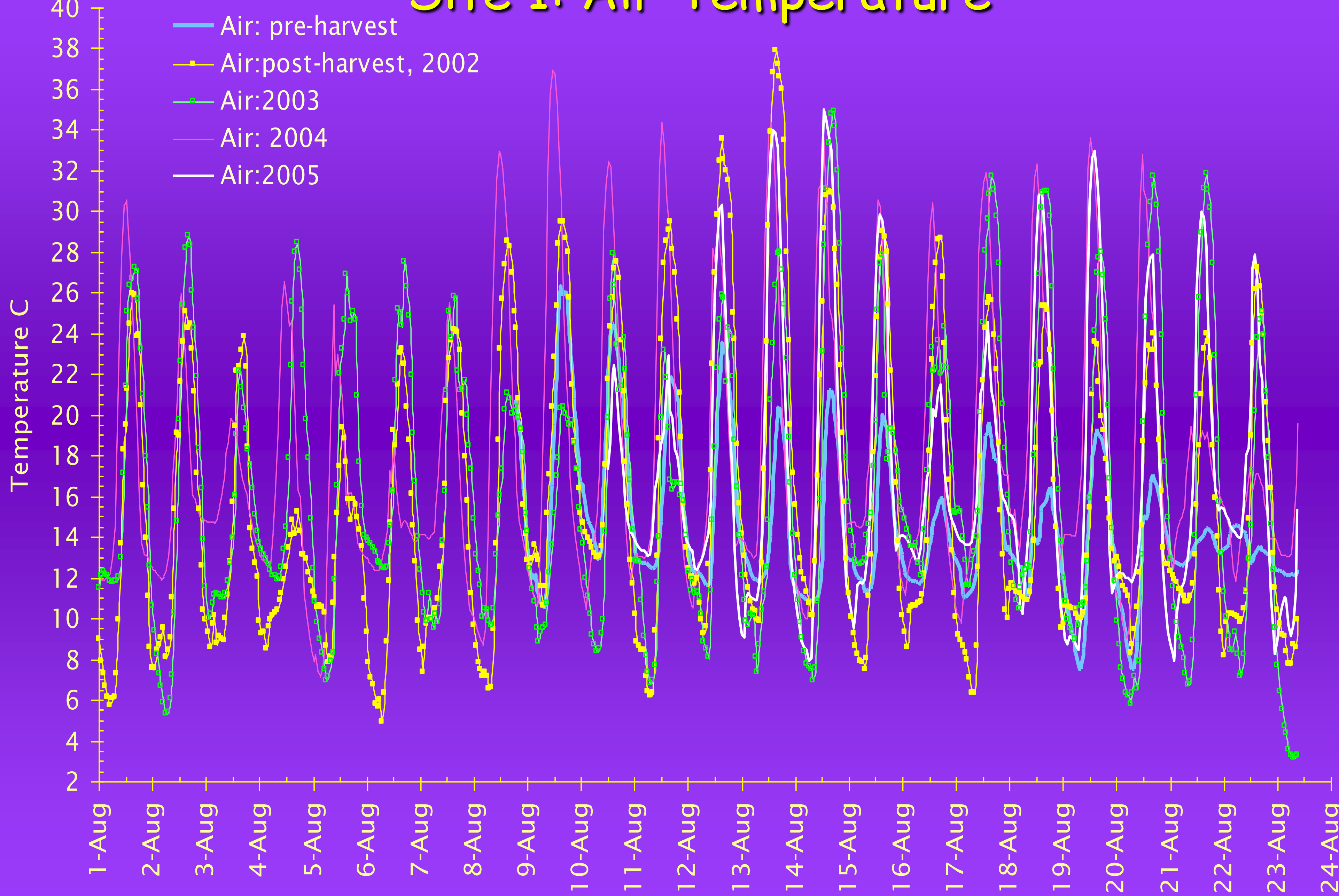
3. What is the relationship between stream, groundwater and soil temperatures and air temperature?

    1. What are the primary variables & mechanisms?

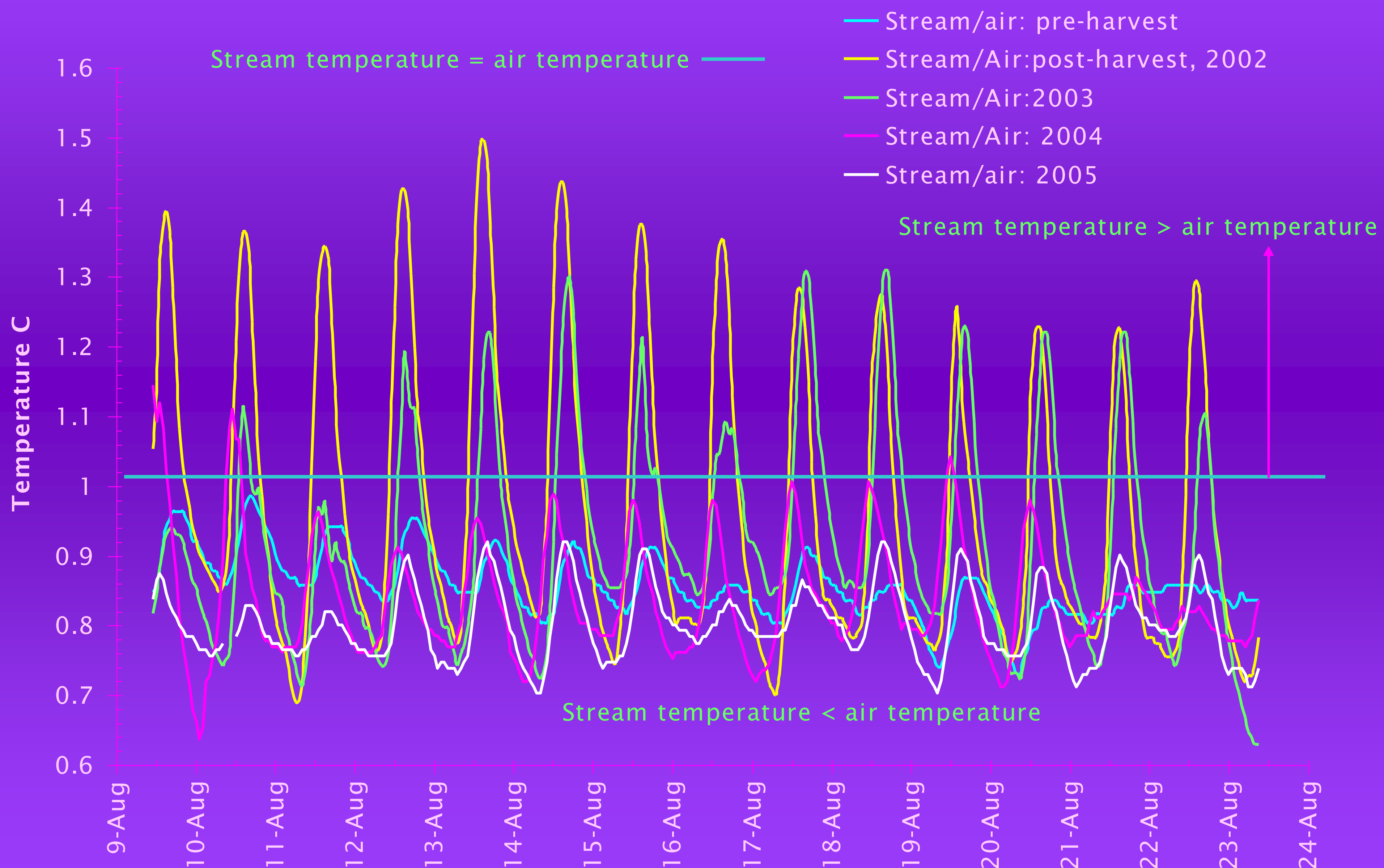
First Test

1. Does canopy removal change air, stream, soil and groundwater temperatures?

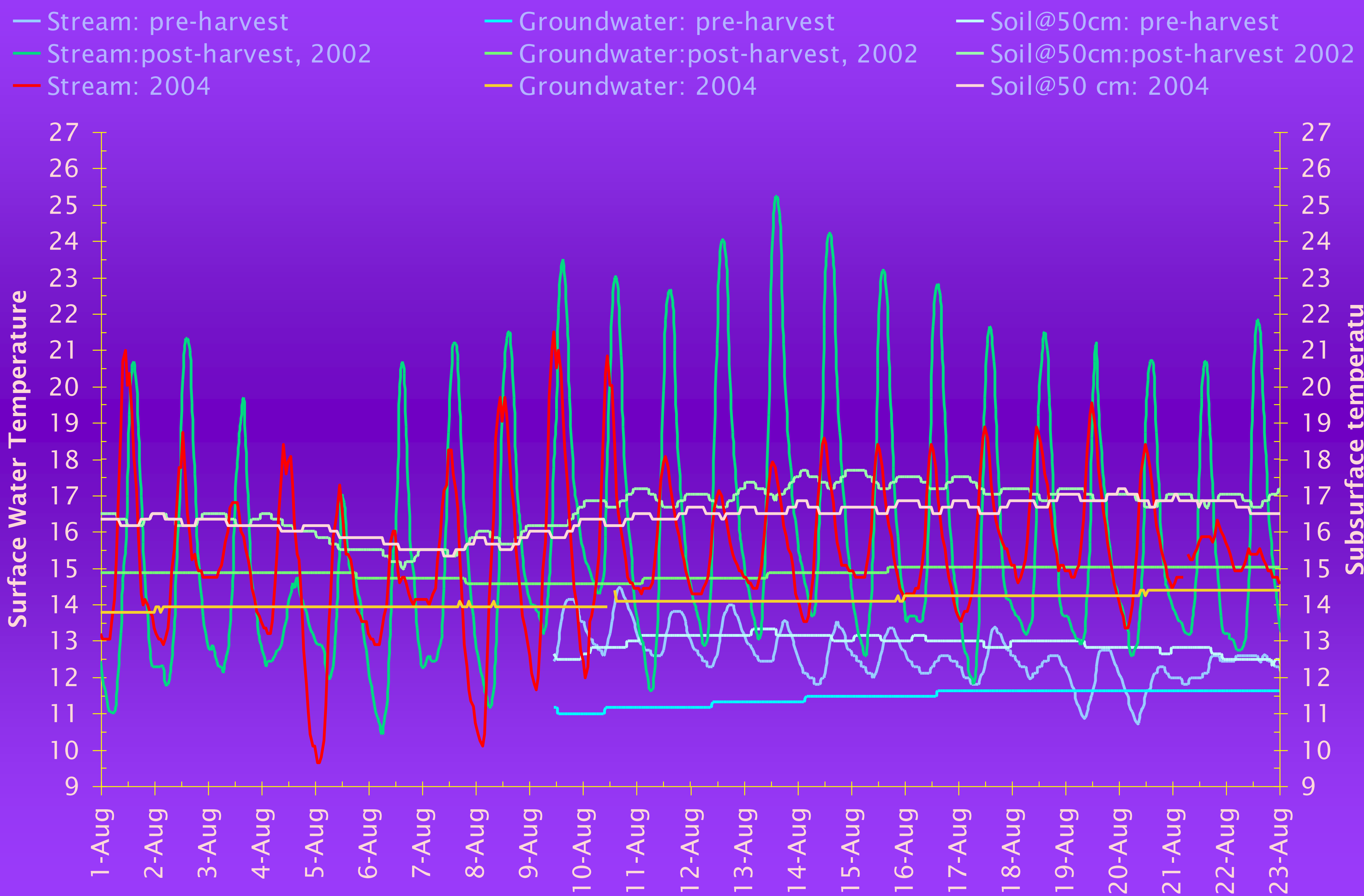
Site 1: Air Temperature



Site 1: Normalized Stream Temperature



Site 1: Water temperatures pre and post harvest



Temperature Comparison: Test Statistics

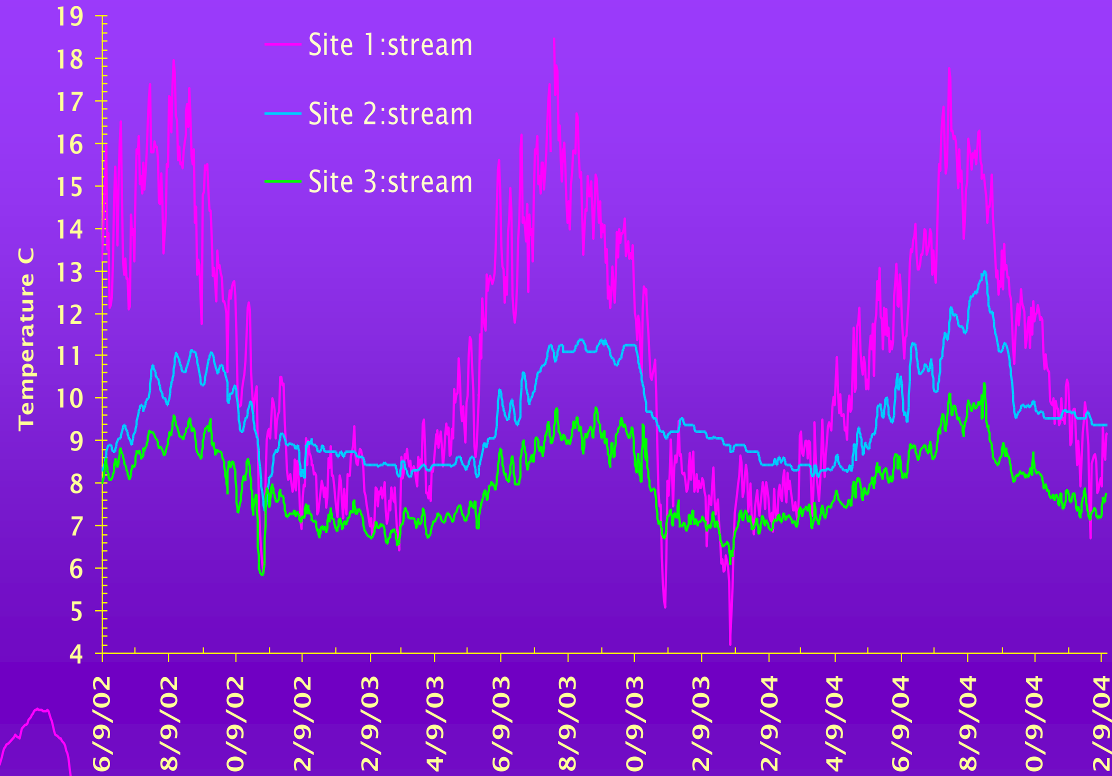
F-Test Two-Sample for Variances

	Air 1	Air 2	Air 1	Air 3	Air 2	Air 3	Soil 2	Groundwater 2
Mean	9.60	8.87	9.60	9.36	8.87	9.36	9.14	9.11
Variance	30.24	22.43	30.24	21.23	22.43	21.23	2.66	2.28
Observations	1133	1129	1133	793	1129	793	1129	1129
P(F<=f) one-tail, CI, 0.05	<<<.0001		<<<.0001		0.2037		0.0049	

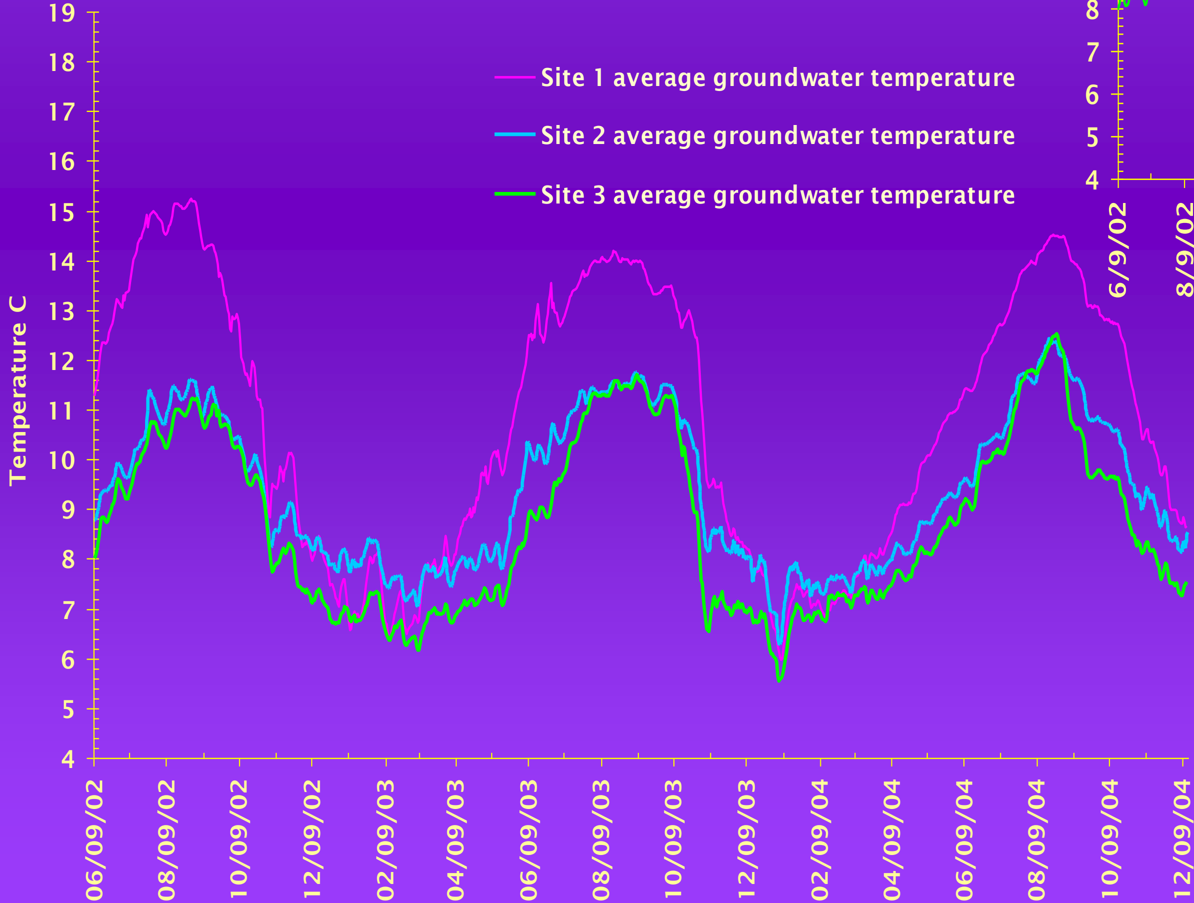
t-Test: Two-Sample for Means — unequal variances | equal variances | unequal variances

	Air 1	Air 2	Air 1	Air 3	Air 2	Air 3	Soil 2	Groundwater 2
Mean	9.60	8.87	9.60	9.36	8.87	9.36	9.14	9.11
Variance	30.24	22.43	30.24	21.23	22.43	21.23	2.66	2.28
Observations	1133	1129	1133	793	1129	793	1129	1129
P(T<=t) two-tail, CI, 0.05	0.0007		0.2961		0.0237		0.5710	

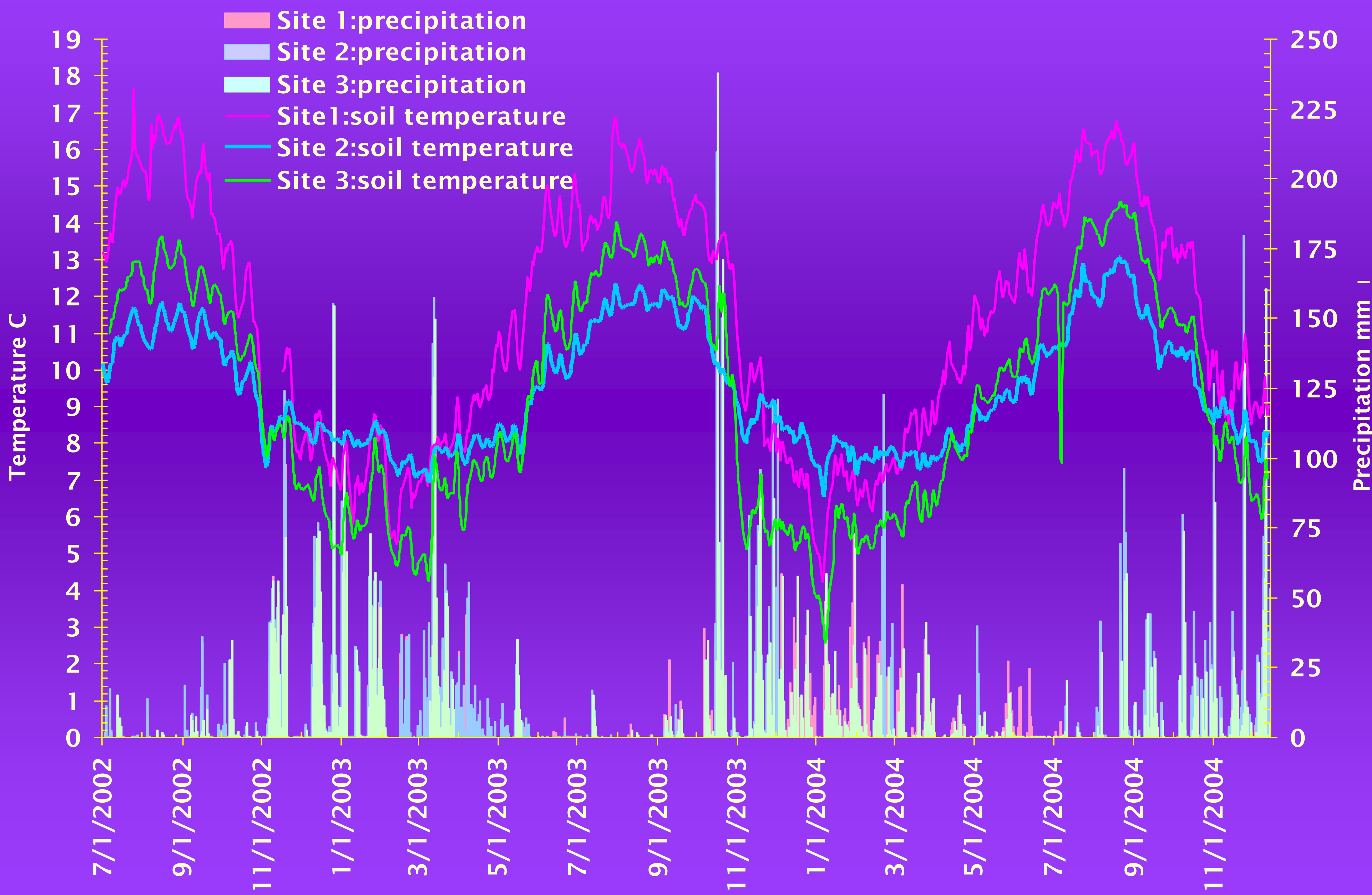
Stream: Comparison



Comparison: Groundwater

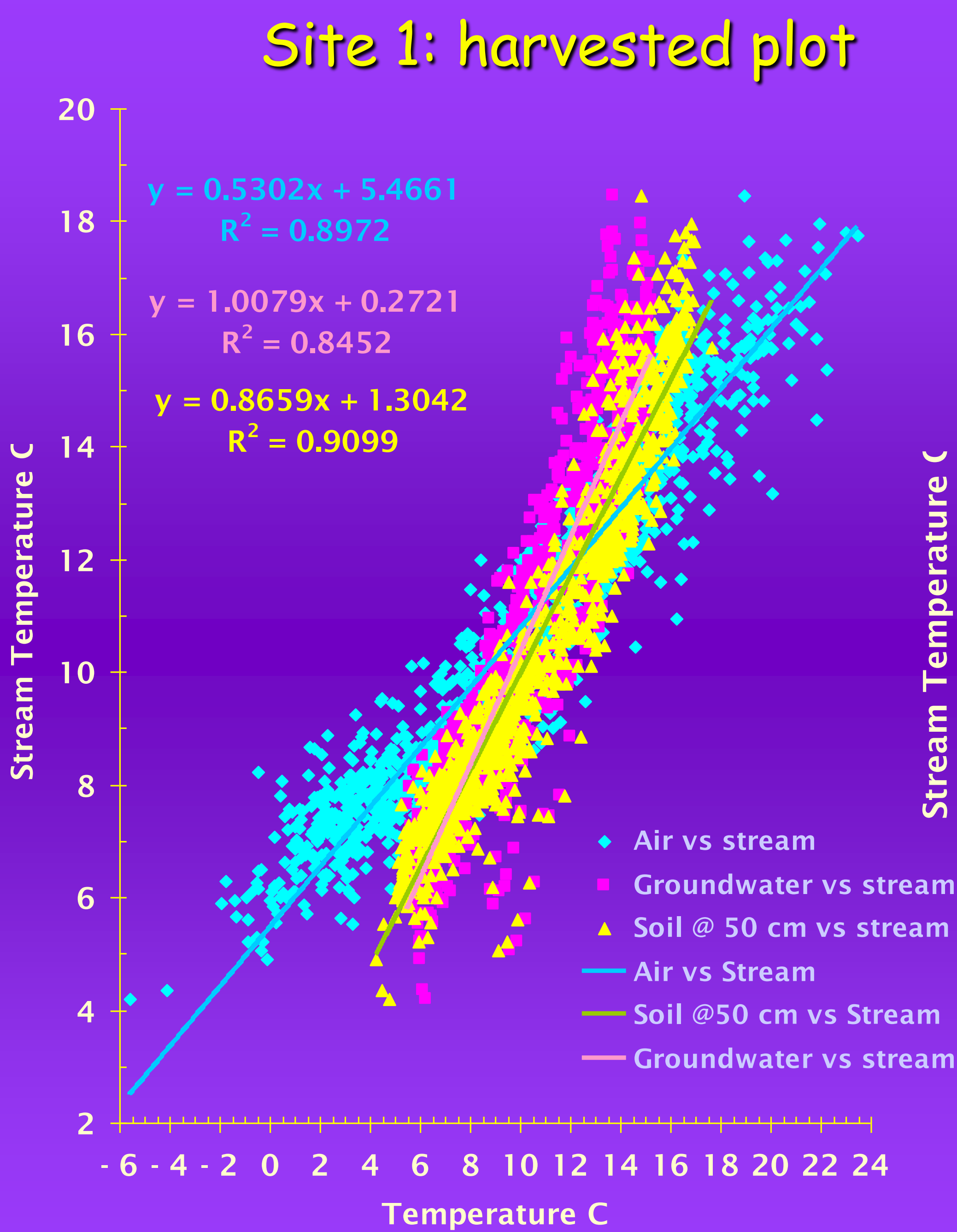


Comparison: Soil at 50 cm depth

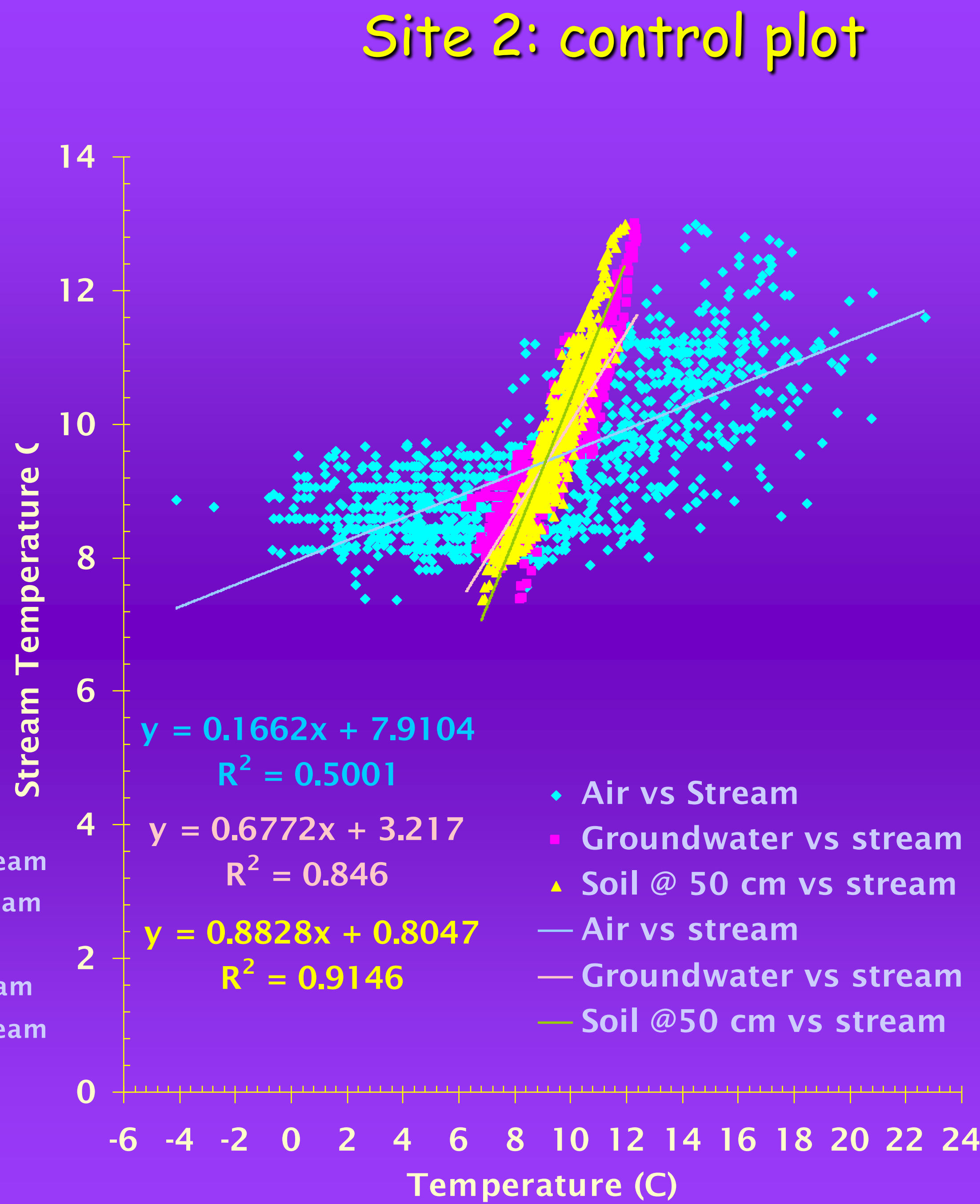


Hypotheses-exploratory analysis

- H_o 2 (general alternative hypothesis): Stream temperatures are significantly related to air temperature
- H_a 2: (general alternative hypothesis): Stream temperatures are significantly related to soil temperatures at 0.5 m depth
- H_a 3 (general alternative hypothesis): Stream temperatures are significantly related to groundwater temperatures

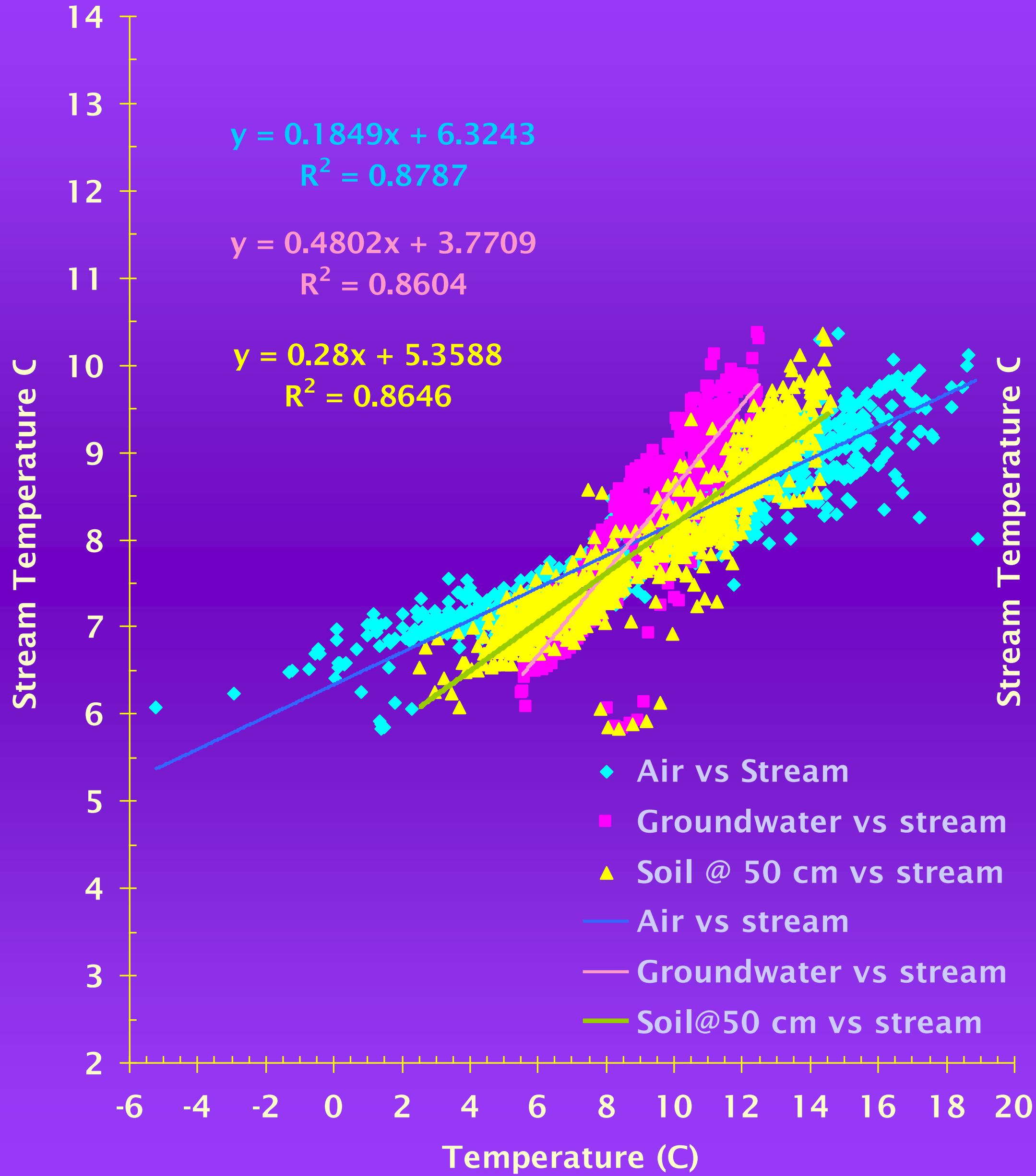


Site 1: harvested plot
y = 0.5302x + 5.4661
R2 = 0.8972
y = 1.0079x + 0.2721
R2 = 0.8452
y = 0.8659x + 1.3042
R2 = 0.9099
Air vs stream
Groundwater vs stream
Soil @ 50 cm vs stream
Air vs Stream
Soil @50 cm vs Stream
Groundwater vs stream
Stream Temperature C
Temperature C

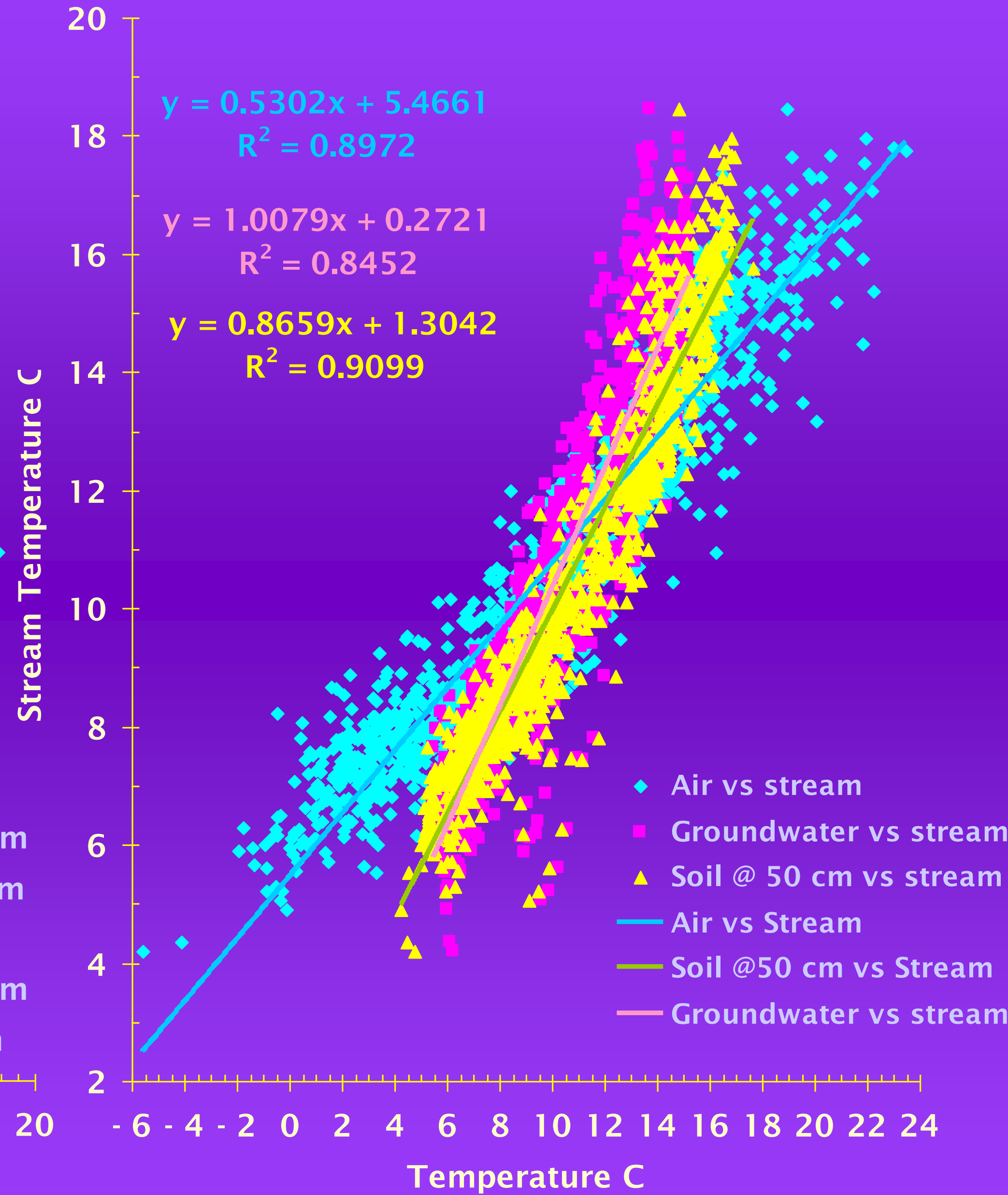


Site 2: control plot
y = 0.1662x + 7.9104
R2 = 0.5001
y = 0.6772x + 3.217
R2 = 0.846
y = 0.8828x + 0.8047
R2 = 0.9146
Air vs Stream
Groundwater vs stream
Soil @ 50 cm vs stream
Air vs stream
Groundwater vs stream
Soil @50 cm vs stream
Stream Temperature (
Temperature (C)

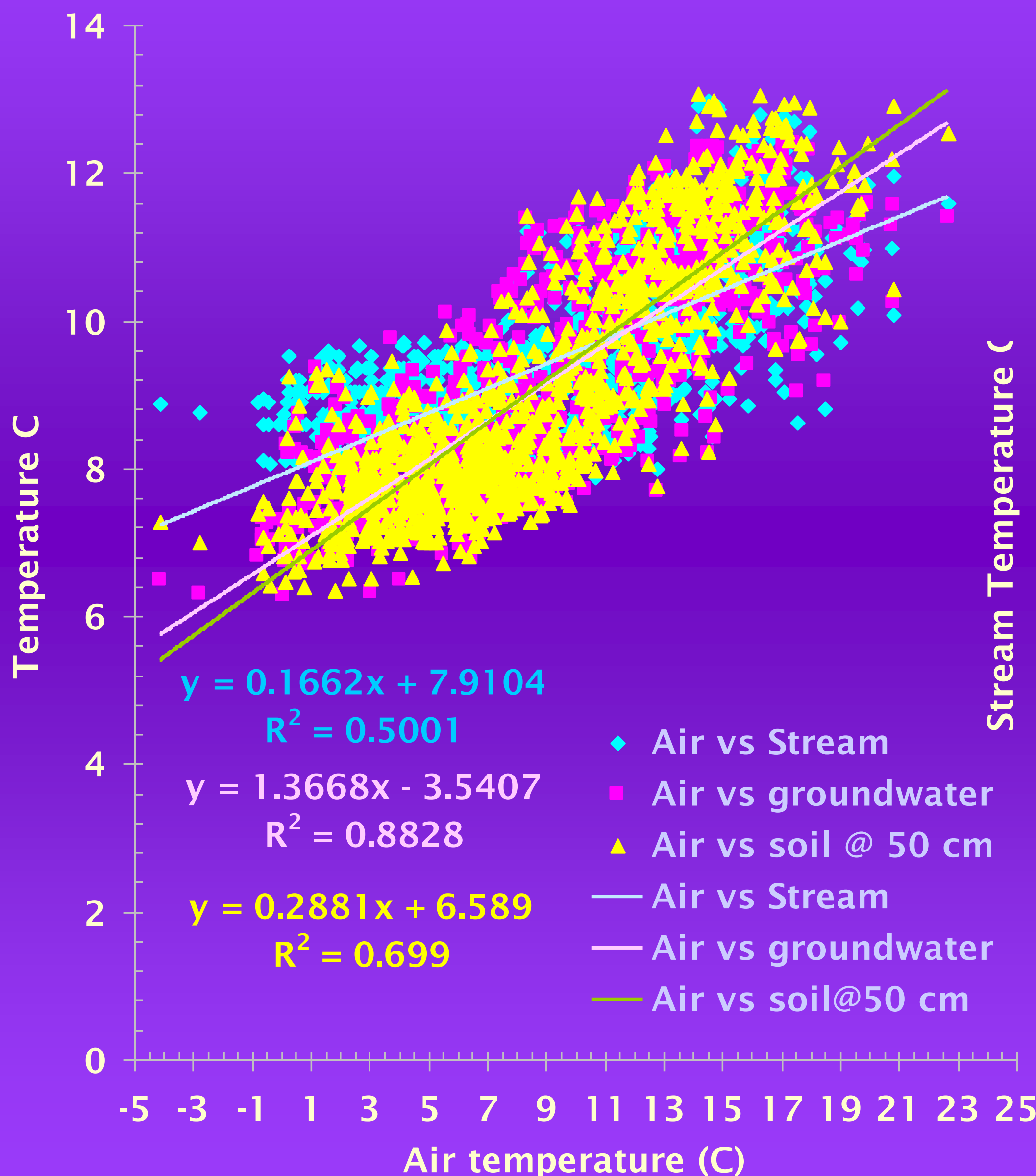
Site 3: reference plot



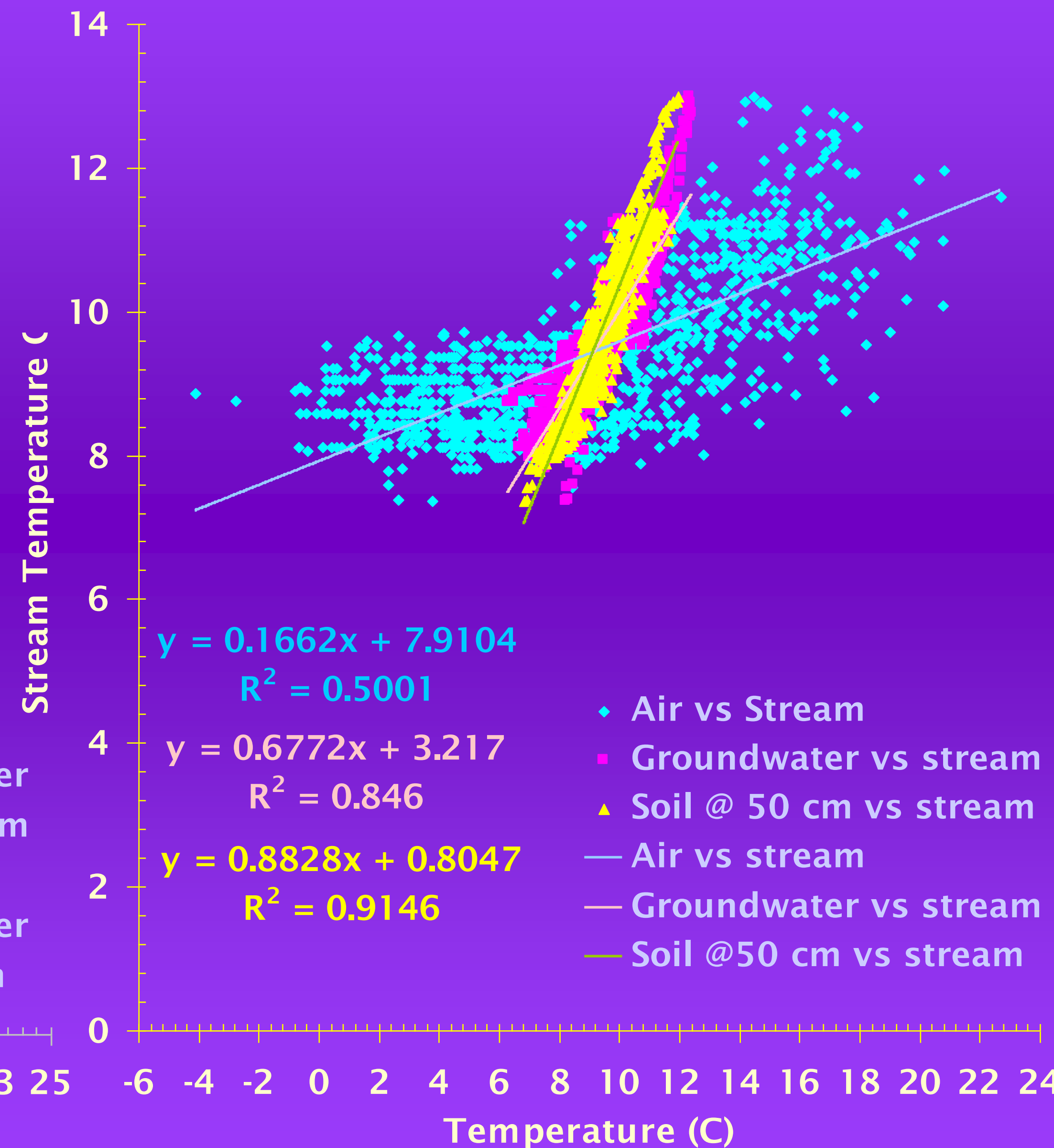
Site 1: harvested plot



Site 2



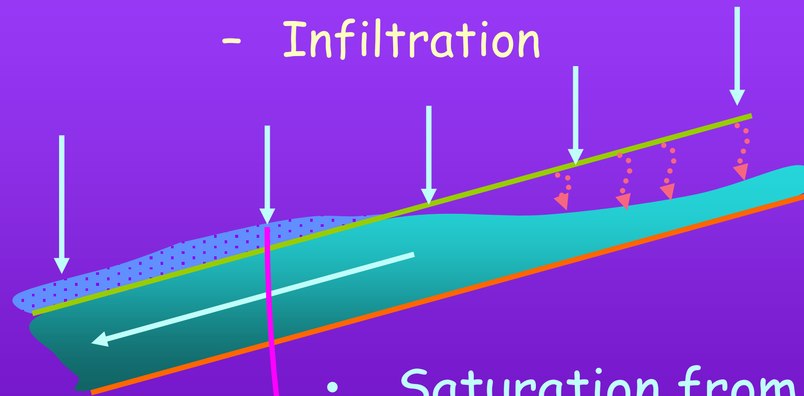
Temperature C
Air temperature (C)
y = 0.1662x + 7.9104
R^2 = 0.5001
y = 1.3668x - 3.5407
R^2 = 0.8828
y = 0.2881x + 6.589
R^2 = 0.699
Air vs Stream
Air vs groundwater
Air vs soil @ 50 cm
Air vs Stream
Air vs groundwater
Air vs soil@50 cm



Stream Temperature C
Temperature (C)
y = 0.1662x + 7.9104
R^2 = 0.5001
y = 0.6772x + 3.217
R^2 = 0.846
y = 0.8828x + 0.8047
R^2 = 0.9146
Air vs Stream
Groundwater vs stream
Soil @ 50 cm vs stream
Air vs stream
Groundwater vs stream
Soil @50 cm vs stream

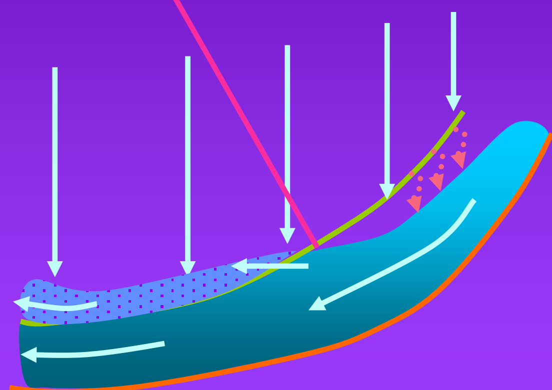
Subsurface to surface water interactions

- Saturation from above
  - Infiltration



- Saturation from below
  - Decreasing K_{sat} at depth

- Local slope break or area of thin soil or change in bedrock



Next Steps

- Compare with data from other sites

- Use subsurface heat transport models to examine:

1. **What are the primary variables affecting the relationship between canopy removal and groundwater temperature (e.g. soil depth, organic matter)?**

2. **Do changes in groundwater quantity and temperature affect stream temperature? What are the primary variables and mechanisms**
   1. Test sensitivity of variables
   2. Identify potential mechanisms