A Curious Caper of Missing Moisture: Nature Hangs in the Balance

59th International Conference on Water Management Modeling
February 25-27, 2026
Toronto, Canada

Mike Gregory, P.Eng., PE (CHI-Guelph, Canada)

also in 59th year

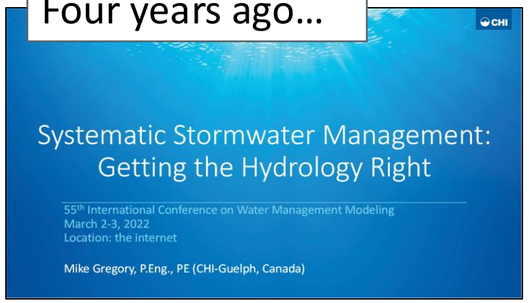
the outline

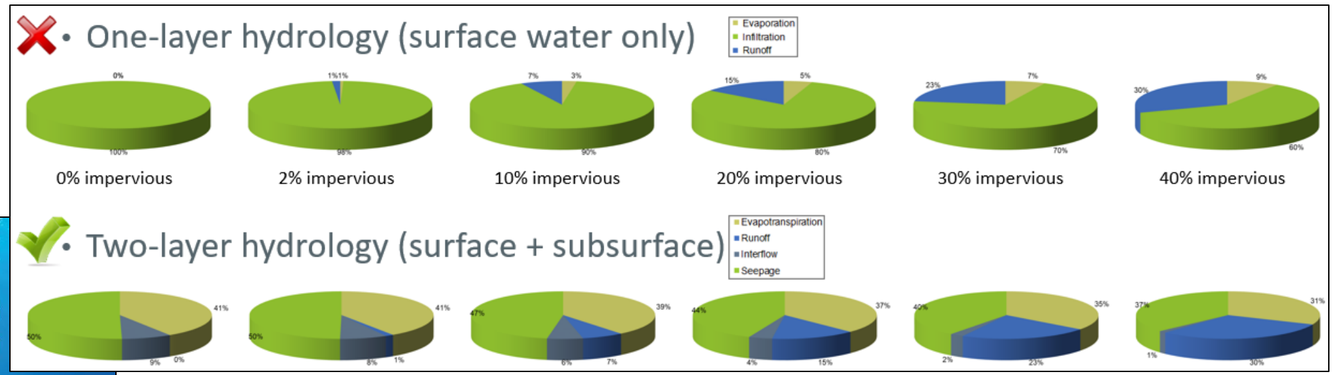
timing	topic	temperament
19:00-16:01	the issue	troubling
16:00-13:31	the solution	improving
13:30-03:01	the application	analyzing
03:00-00:00	the offer	giving

the issue // explained

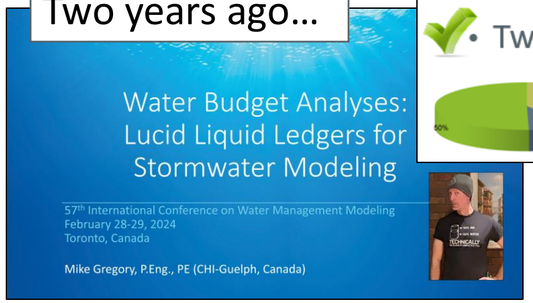
- A distinction between hydrology methods for various modeling applications
  - Flooding/erosion control: extreme rainfall/loading conditions only
  - Quality treatment, volume control, environmental flow maintenance: the full range
- It's OK to ignore evapotranspiration for flooding, but not for everything else
- Recent presentations at this conference…
  - Regular "one-layer" SWMM5 Hydrology needs help to get ET
  - Flow duration curves for 13 unique hydrologic response units

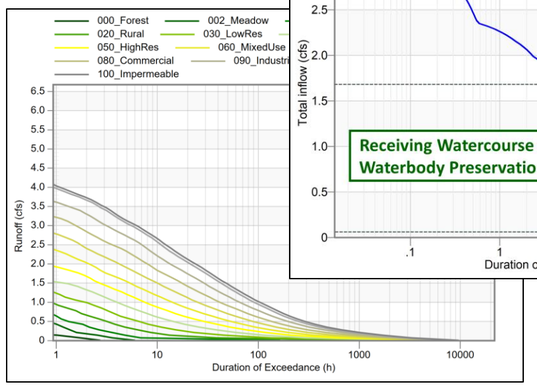
Four years ago…

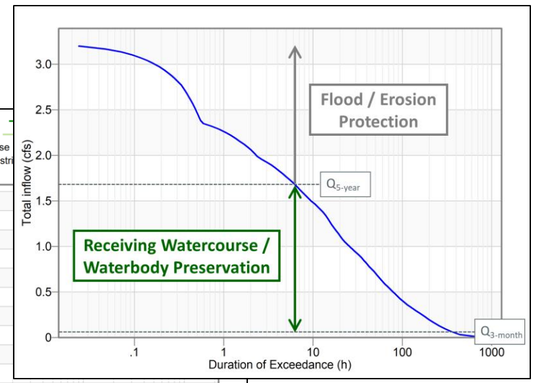




Two years ago…







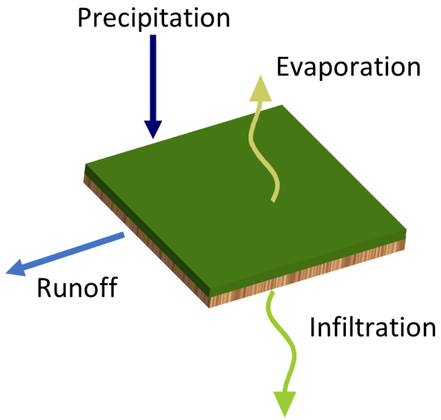
19:00

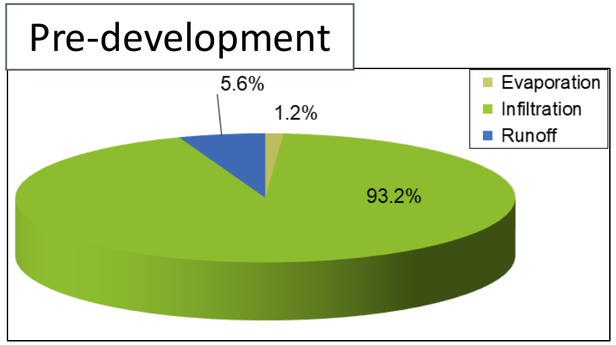
the issue // explained even further

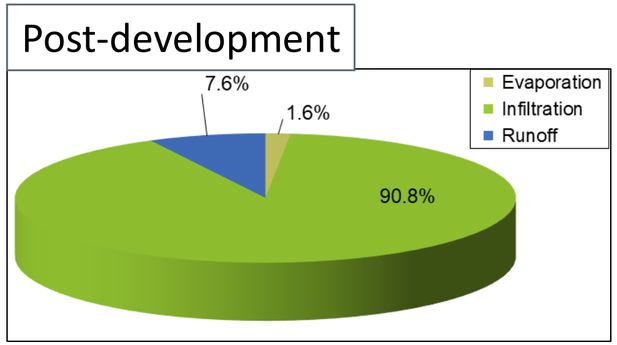
- Water budget is an equation, often tabulated
- Water balance is a piece of the pie, often charted
  - The right side of the water budget equation
  - Modelers aim for Δ Storage and continuity errors = 0
- One-layer water budget/balance example…

Precipitation + Runon =
Evapotranspiration + Runoff + Infiltration + Δ Storage

Evapotranspiration + Runoff + Infiltration = 100%







Surface Hydrology	Average Annual Water Budget (in/yr)			
	Pre-Devpt		Post-Devpt	
Precipitation	39.7	100.0%	39.7	100.0%
Evaporation	0.5	1.2%	0.6	1.6%
Infiltration	37.0	93.2%	36.1	90.8%
Runoff	2.2	5.6%	3.0	7.6%

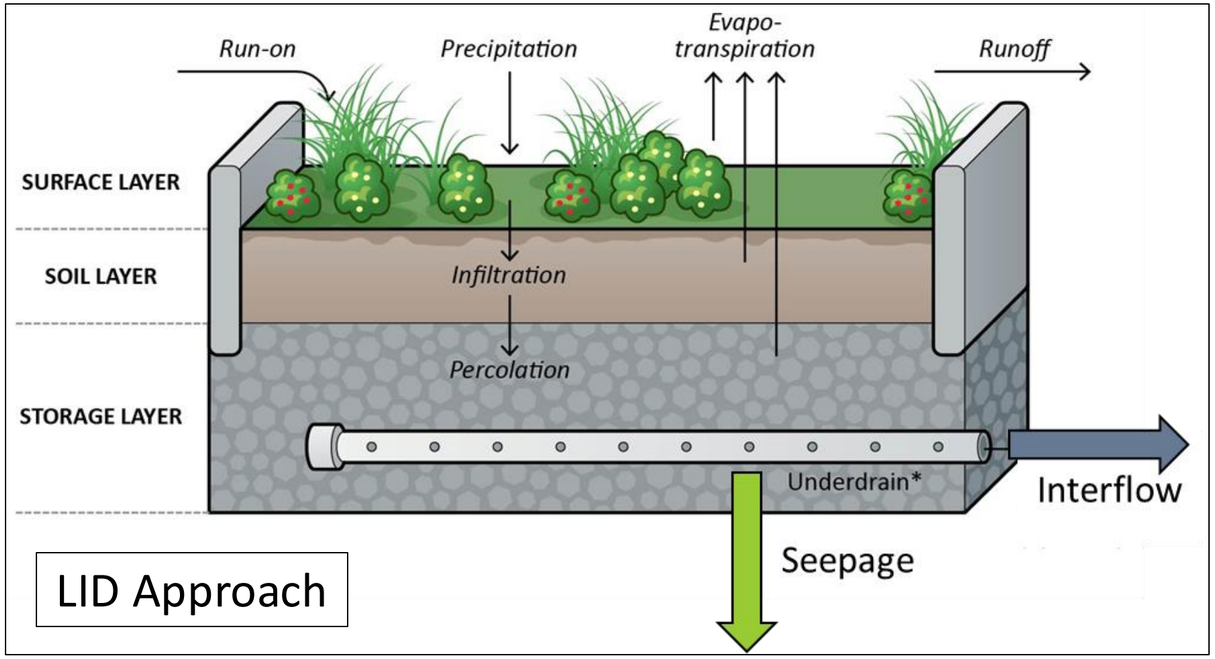
- Unbalanced budget!

50-70% ET is expected in this climate region (not 1-2%)!

17:30

the solution // that way

- Method 1: Add an LID control
  - Infiltrated water from the Surface layer is tracked in two subsurface layers: Soil layer + Storage layer



LID Approach

- More on that tomorrow…

2026 Conference Program

Session 6

10:40 AM
Hybrid Nonlinear Reservoir Routing Algorithm (HNRA): A Time of Concentration-Agnostic Approach for the Rational Method Framework
Excie Guillot, **Jose Vasconcelos,** and Xing Fang, Auburn University, AL, USA

11:00 AM
Enhancing Urban Water Balance Representation in EPA SWMM Using a Two-Layer Infiltration Approach
Sherif S. Ahmed, Craig Kipkie, Tara Paradis, and Lotte Veth, Kerr Wood Leidal Associates Ltd, BC, Canada, Alexa Baker and Bert van Duin, City of Calgary, AB, Canada

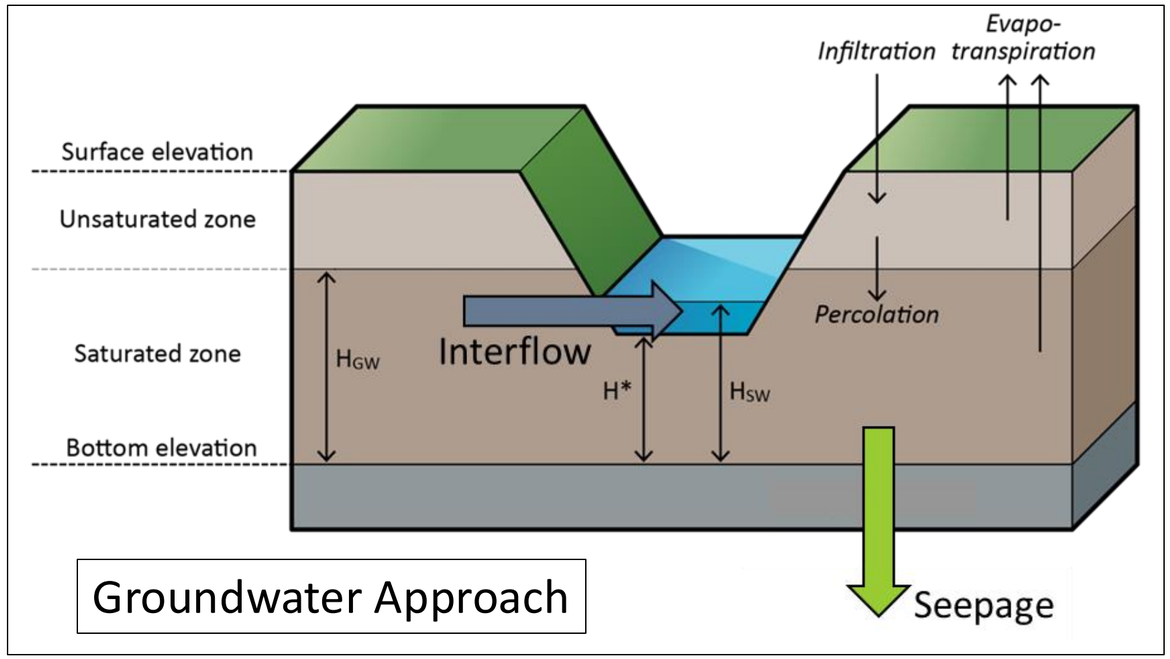
11:20 AM
Hydrologic Model Comparisons Between MIKE+ Model B Kinematic Wave and SWMM Subcatchment Runoff with Horton Infiltration
Suibing Liu, Jacobs, OH, USA

11:40 AM
Taking a Deep Dive with the JWMM
Laura-Lee Fletcher, Computational Hydraulics Inc. (CHI), ON, Canada

16:00

the solution // this way

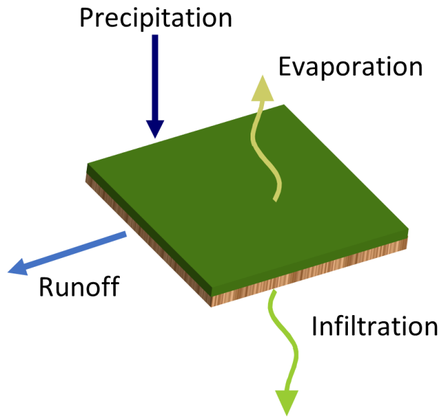
- Method 2: Add a groundwater aquifer
  - Aquifer receives infiltrated water from the surface hydrology compartment
  - Water is tracked in two zones of the groundwater compartment: unsaturated upper zone and saturated lower zone



the solution // this way, exampled

- Composite ET = Surface Evaporation + Subsurface ET (Upper + Lower Zone Evapotranspiration)
- A two-layer approach balances the budget

Composite Hydrology	Hydrologic Water Balance (in/yr)			
	Pre-Devpt		Post-Devpt	
Evapotranspiration	25.0	62.8%	24.4	61.5%
Surface Runoff	2.2	5.6%	3.0	7.6%
Groundwater Interflow	1.3	3.2%	1.1	2.7%
Groundwater Seepage	11.3	28.4%	11.2	28.2%
Total	**39.7**	**100.0%**	**39.7**	**100.0%**



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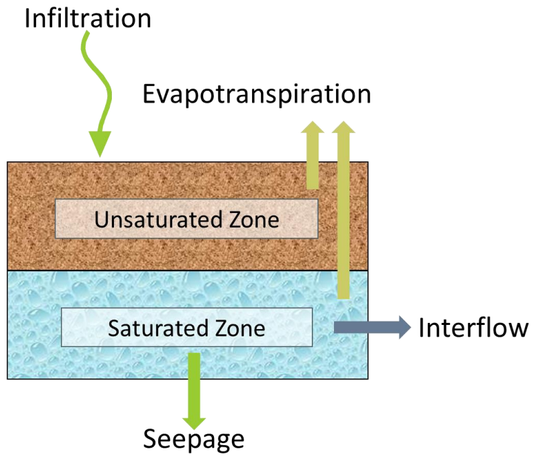
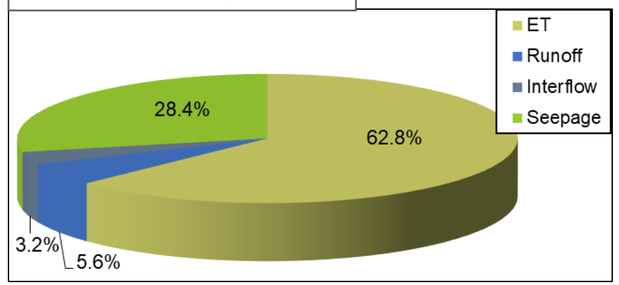


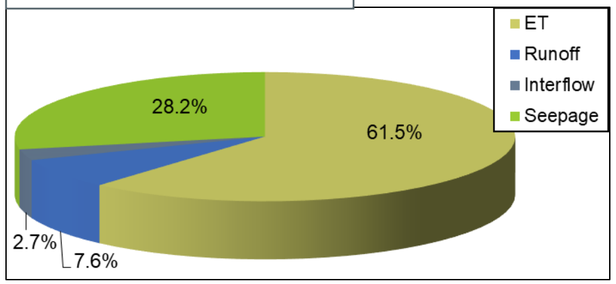
Subsurface Hydrology	Average Annual Water Budget (in/yr)			
	Pre-Devpt		Post-Devpt	
Infiltration	37.0	100.0%	36.1	100.0%
Upper Zone ET	24.0	64.8%	23.3	64.6%
Lower Zone ET	0.5	1.3%	0.5	1.4%
Groundwater Interflow	1.3	3.4%	1.1	3.0%
Groundwater Seepage	11.3	30.4%	11.2	31.1%
Δstorage + c.e.	-0.01	0.0%	-0.02	0.0%

Pre-development



ET approved!

Post-development



15:00

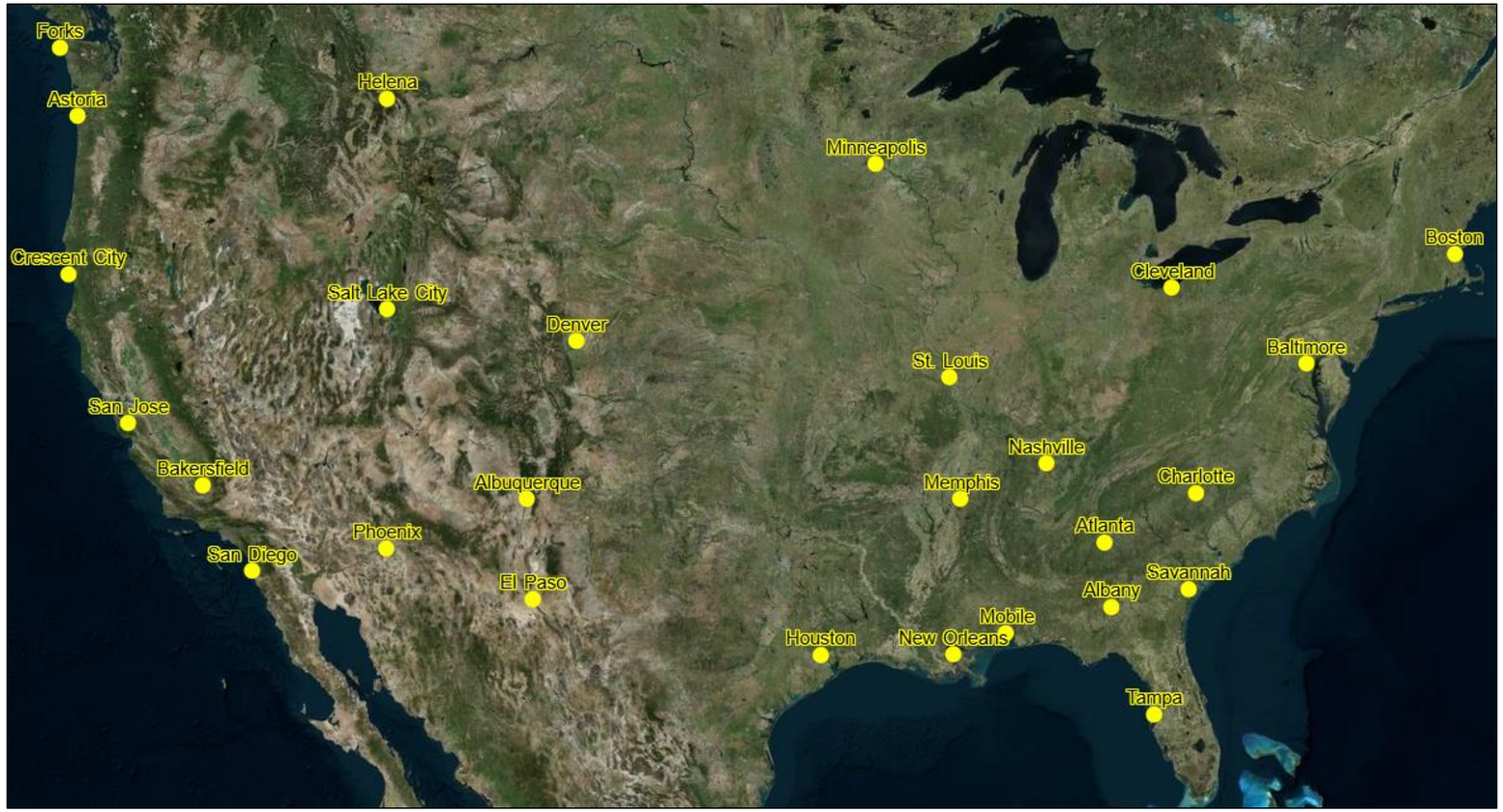
the application // cast of characters

- 27 standardized water balance models
- Equal groupings by average annual rainfall and daily air temperature

Dry (<25 in)
Moderate (25-50 in)
Wet (>50 in)

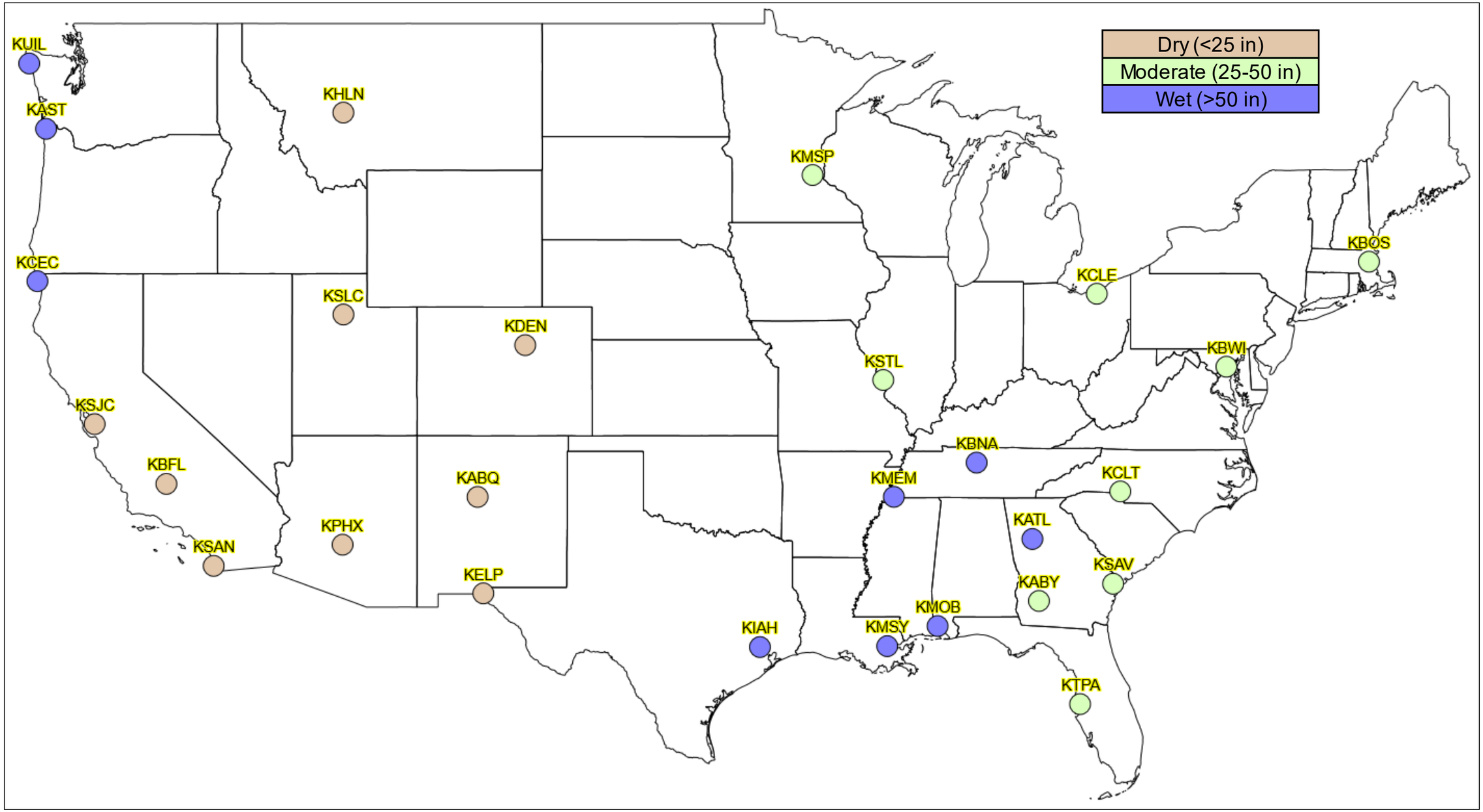
Cold (<55°F)
Temperate (55-65°F)
Hot (>65°F)

Model Location			Simulaton Period			Precip	Air Temp
City	Airport	Code	Start	End	yr	in/yr	°F
Albany, GA	Southwest Georgia Regional	KABY	2005	2020	15	47	68
Albuquerque, NM	Albuquerque Int'l Sunport	KABQ	1947	2014	66	9	58
Astoria, OR	Astoria Regional	KAST	1990	2020	30	70	51
Atlanta, GA	Hartsfield-Jackson Atlanta Int'l	KATL	1948	2014	66	50	64
Bakersfield, CA	Meadows Field	KBFL	1948	2014	65	6	66
Baltimore, MD	Baltimore/Washington Int'l	KBWI	1948	2011	63	45	56
Boston, MA	Logan Int'l	KBOS	1949	2014	65	44	52
Charlotte, NC	Charlotte Douglas Int'l	KCLT	1948	2014	66	44	61
Cleveland, OH	Cleveland Hopkins Int'l	KCLE	1948	2014	65	41	52
Crescent City, CA	Del Norte County Regional	KCEC	2005	2020	15	58	53
Denver, CO	Denver Int'l	KDEN	1996	2020	24	15	51
El Paso, TX	El Paso Int'l	KELP	1948	2014	66	9	66
Forks, WA	Quillayute	KUIL	1990	2020	30	101	50
Helena, MT	Helena Regional	KHLN	1948	2014	66	11	46
Houston, TX	George Bush Intercont'l	KIAH	1970	2014	44	52	71
Memphis, TN	Memphis Int'l	KMEM	1990	2020	30	55	63
Minneapolis, MN	Minneapolis-Saint Paul Int'l	KMSP	1948	2011	63	32	47
Mobile, AL	Mobile Regional	KMOB	1990	2020	30	67	68
Nashville, TN	Nashville Int'l	KBNA	1948	2014	65	51	61
New Orleans, LA	Louis Armstrong N.O. Int'l	KMSY	1948	2014	66	63	71
Phoenix, AZ	Phoenix Sky Harbor Int'l	KPHX	1948	2014	66	7	76
Salt Lake City, UT	Salt Lake City Int'l	KSLC	1948	2014	66	16	55
San Diego, CA	San Diego Int'l	KSAN	1948	2014	66	10	65
San Jose, CA	San José Mineta Int'l	KSJC	2001	2020	19	16	62
Savannah, GA	Savannah/Hilton Head Int'l	KSAV	1948	2014	66	48	68
St. Louis, MO	St. Louis Lambert Int'l	KSTL	1948	2014	65	42	57
Tampa, FL	Tampa Int'l	KTPA	1958	2014	56	50	75

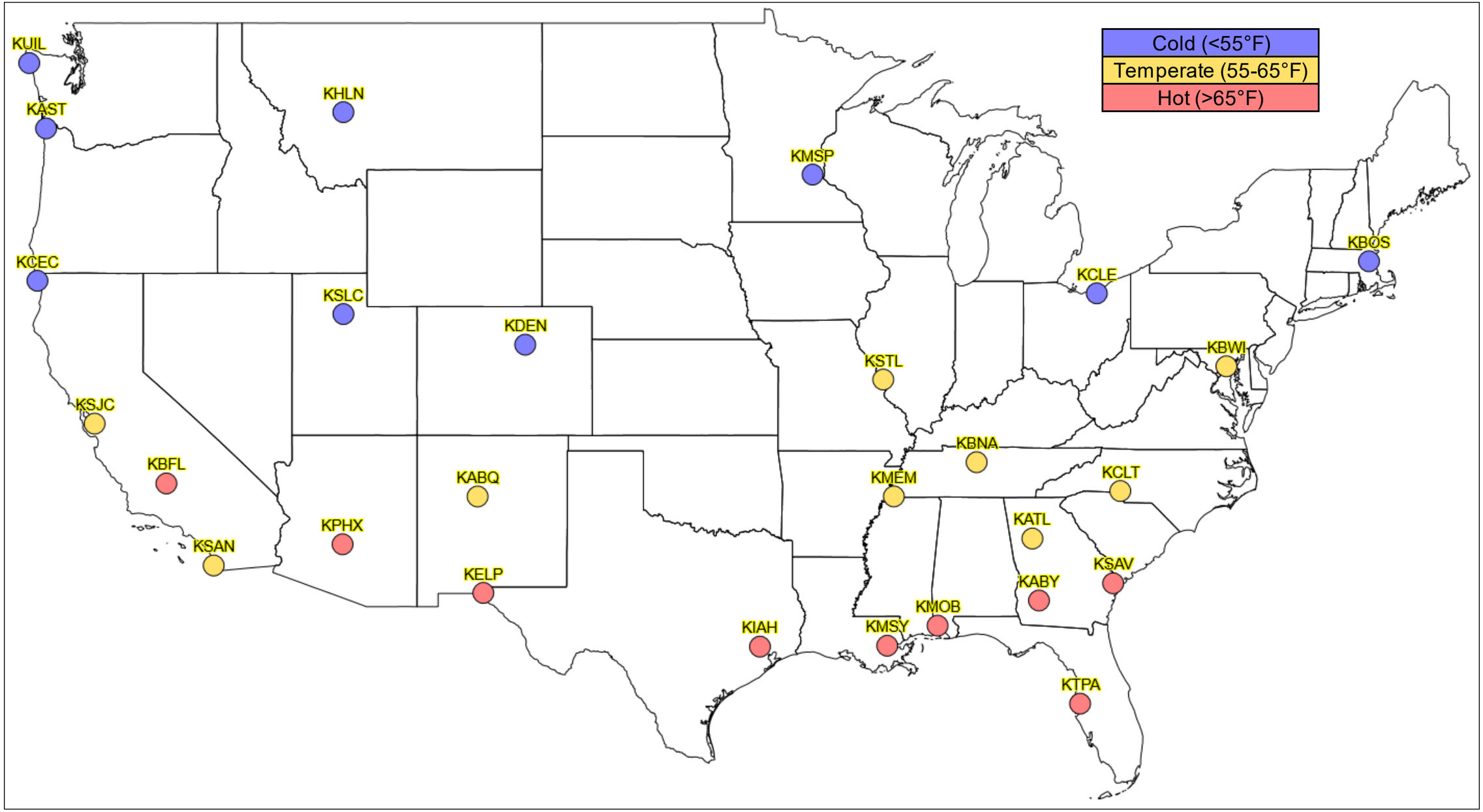


13:30

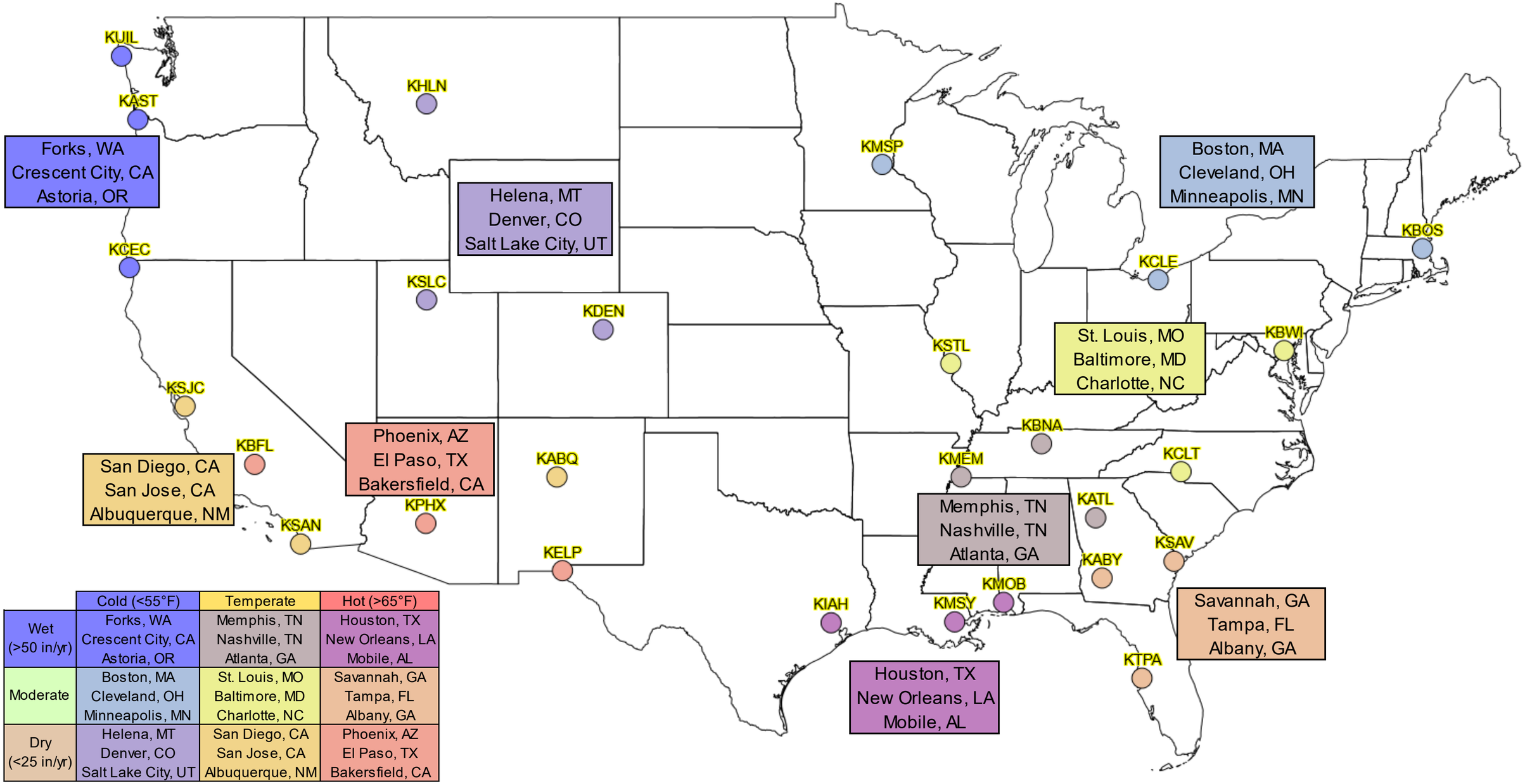
Water Balance Models (by annual precipitation)



Water Balance Models (by average temperature)



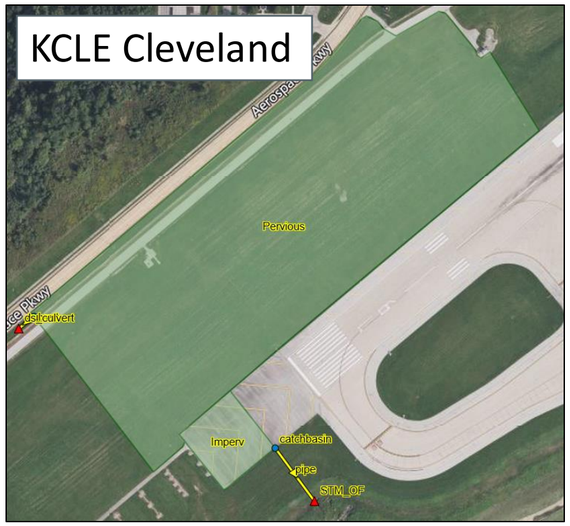
Water Balance Models (by climate cohort)

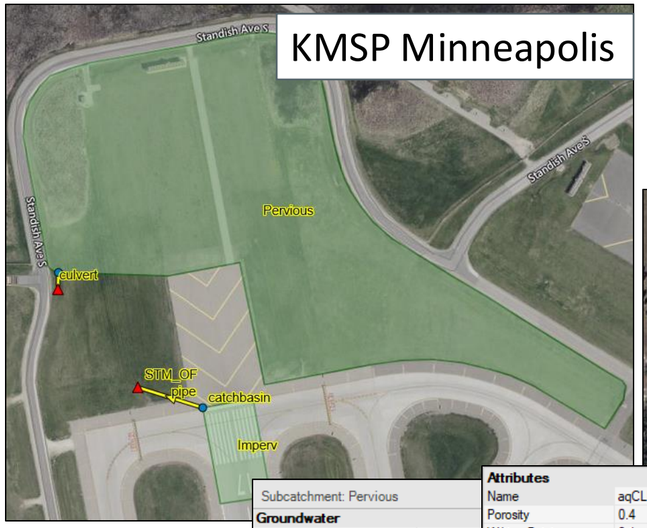


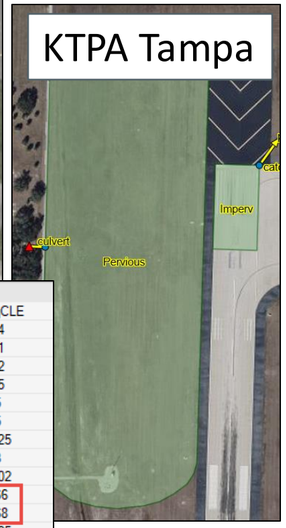
	Cold (<55°F)	Temperate	Hot (>65°F)
Wet (>50 in/yr)	Forks, WA Crescent City, CA Astoria, OR	Memphis, TN Nashville, TN Atlanta, GA	Houston, TX New Orleans, LA Mobile, AL
Moderate	Boston, MA Cleveland, OH Minneapolis, MN	St. Louis, MO Baltimore, MD Charlotte, NC	Savannah, GA Tampa, FL Albany, GA
Dry (<25 in/yr)	Helena, MT Denver, CO Salt Lake City, UT	San Diego, CA San Jose, CA Albuquerque, NM	Phoenix, AZ El Paso, TX Bakersfield, CA

the application // character shout-outs

- Local meteorological inputs & climate variables, standard H&H…
- Hydrology
  - 1-ac 100% impervious subcatchment (snow plowed onto pervious)
  - 20-ac 100% pervious subcatchment (no plowing)
  - Common slope, overland flow, infiltration parameters
- Hydraulics
  - 2-ft Ø pipe on 1% slope (impervious)
  - 3-ft Ø culvert on 1% slope (pervious)
- Groundwater
  - Common soil parameters (sandy loam texture) and initial soilwater content (0.25)
  - Groundwater elevations relative to ground surface: bottom of aquifer = ground-14ft, initial water table = ground-12ft)







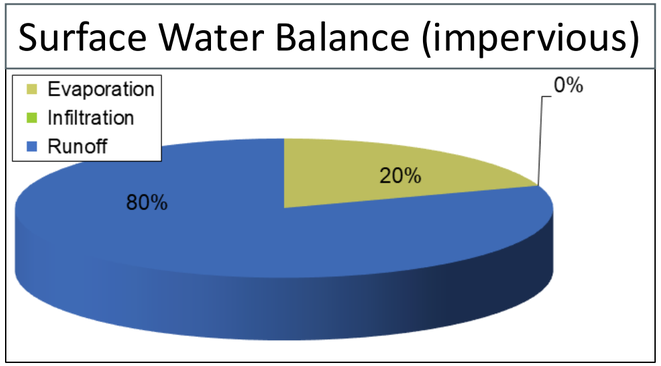
Subcatchment: Pervious	
Groundwater	
Aquifer Name	aqCLE
Receiving Node	us_culvert
Surface Elevation (ft)	780
A1 Coefficient	0
B1 Exponent	0
A2 Coefficient	0
B2 Exponent	0
A3 Coefficient	0
Surface Water Depth (ft)	0
Threshold Water Table Elev.	-99
Bottom Elevation (ft)	-99
Initial Elevation (ft)	-99
Initial Moisture (fraction)	-99
Lateral Flow Equation	100000*KS*(Hgw-Hcb)^2/1000^2
Deep Flow Equation	0.01*Hgw/Hgs

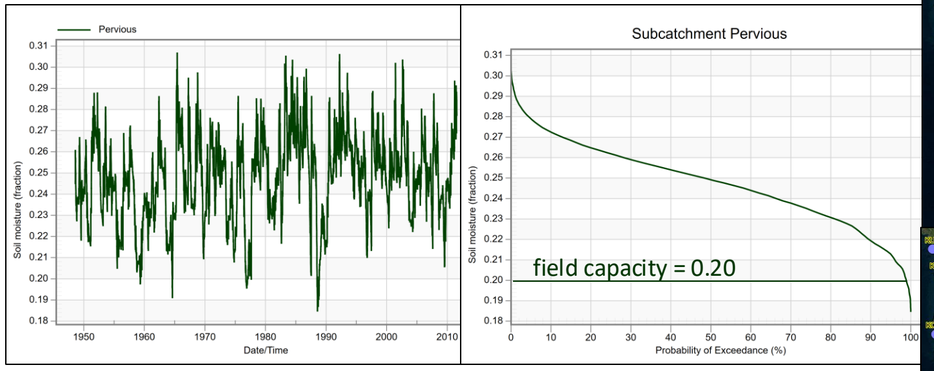
Attributes	
Name	aqCLE
Porosity	0.4
Wilting Point	0.1
Field Capacity	0.2
Conductivity	0.5
Conduct. Slope	45
Tension Slope	15
Upper Evap. Fraction	0.25
Lower Evap. Depth	13
Lower GW Loss Rate	0.02
Bottom Elevation	766
Water Table Elevation	768
Unsat. Zone Moisture	0.25
Upper Evap. Pattern	AquiferET

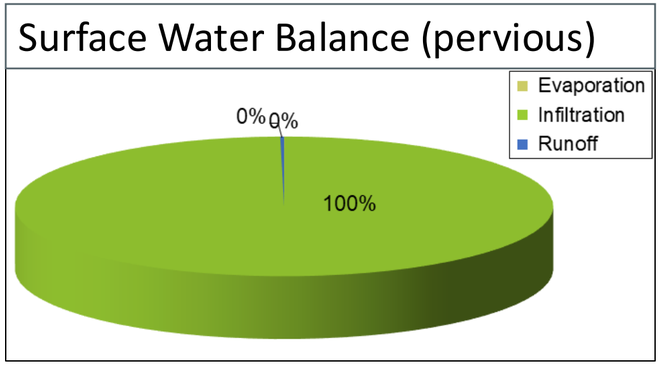
12:30

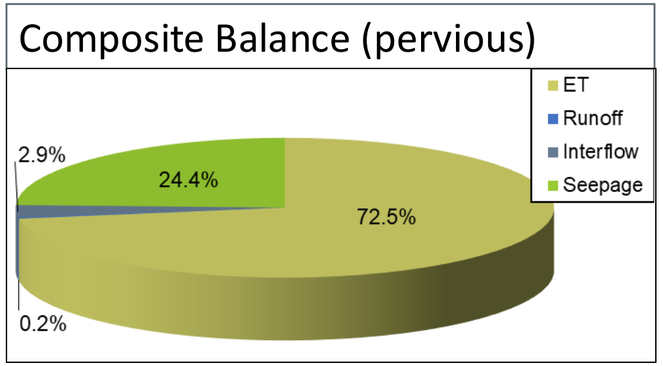
the application // pie chart overload

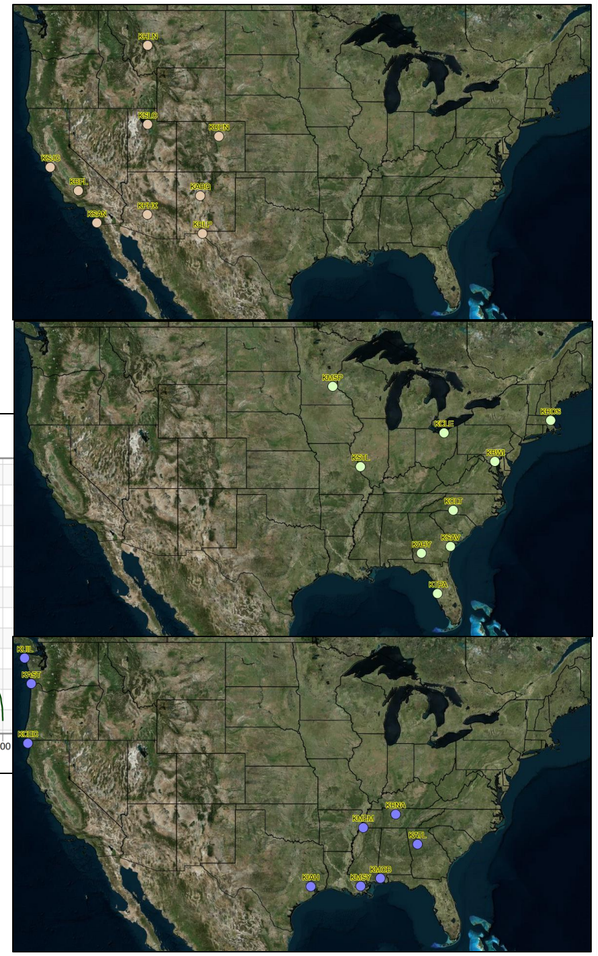
- Expectation… (but didn't find many wet climates)
  - 90-100% ET in dry climates (<15 in/yr)
  - 50-70% ET in moderate climates
  - 15-25% ET in wet climates (>75 in/yr)
- Example for Minneapolis, MN











Model Location	Precip in/yr	
Bakersfield, CA	6.4	Dry (<25 in/yr)
Phoenix, AZ	7.2	
Albuquerque, NM	8.8	
El Paso, TX	8.8	
San Diego, CA	9.8	
Helena, MT	11.4	
Denver, CO	14.5	
Salt Lake City, UT	15.5	
San Jose, CA	16.1	
Minneapolis, MN	31.6	Moderate (25-50)
Cleveland, OH	41.0	
St. Louis, MO	41.7	
Boston, MA	43.6	
Charlotte, NC	43.6	
Baltimore, MD	45.0	
Albany, GA	46.6	
Savannah, GA	48.1	
Tampa, FL	49.5	
Atlanta, GA	50.4	Wet (>50 in/yr)
Nashville, TN	50.5	
Houston, TX	51.8	
Memphis, TN	54.9	
Crescent City, CA	58.0	
New Orleans, LA	63.4	
Mobile, AL	67.1	
Astoria, OR	70.3	
Forks, WA	101.3	

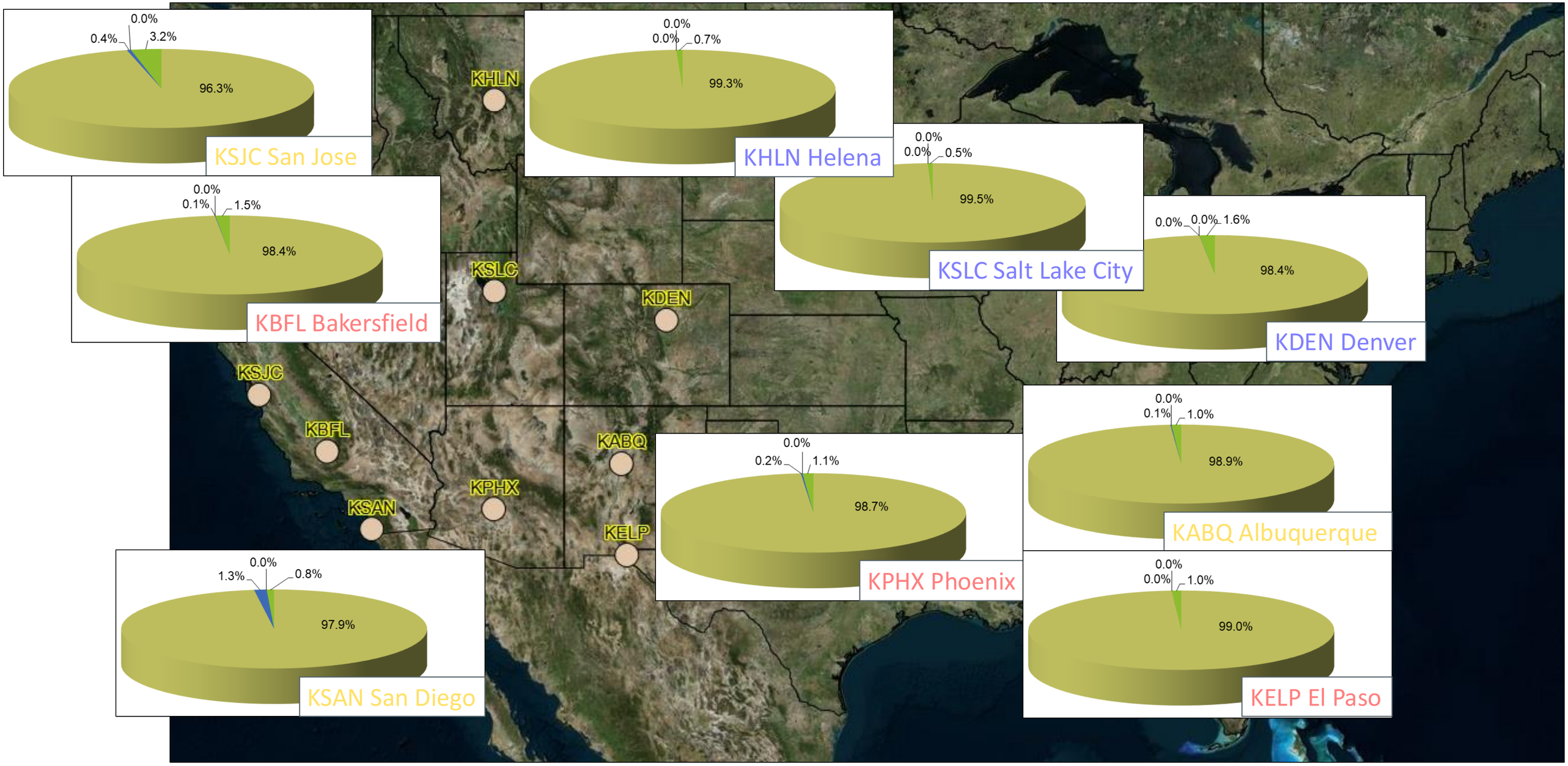
10:30

The Dry Places

	ET
min	96%
avg	98%
max	100%

ET
Runoff
Interflow
Seepage

Cold (<55°F)
Temperate (55-65°F)
Hot (>65°F)

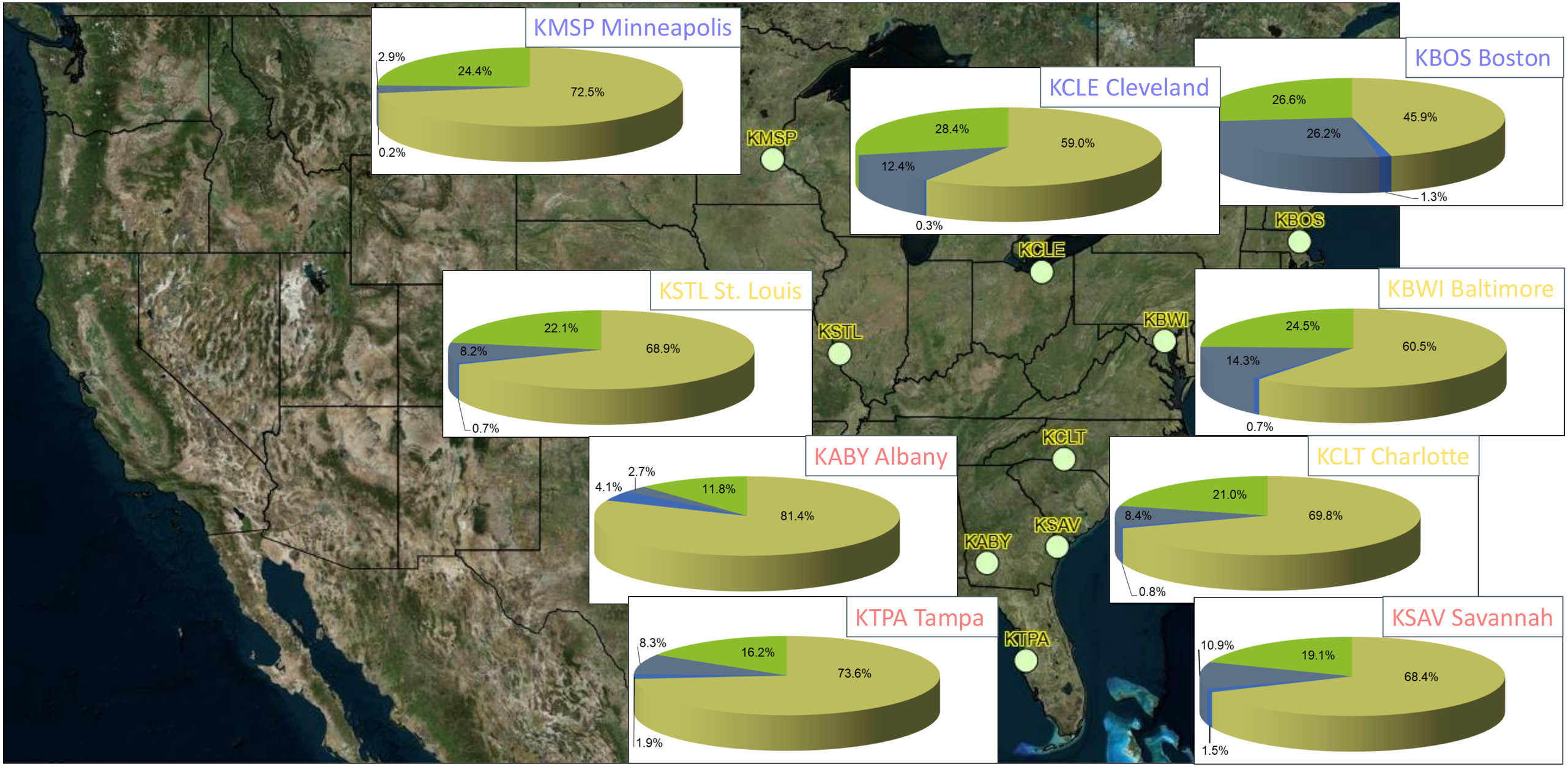


Moderate

	ET
min	46%
avg	67%
max	81%

ET
Runoff
Interflow
Seepage

Cold (<55°F)
Temperate (55-65°F)
Hot (>65°F)

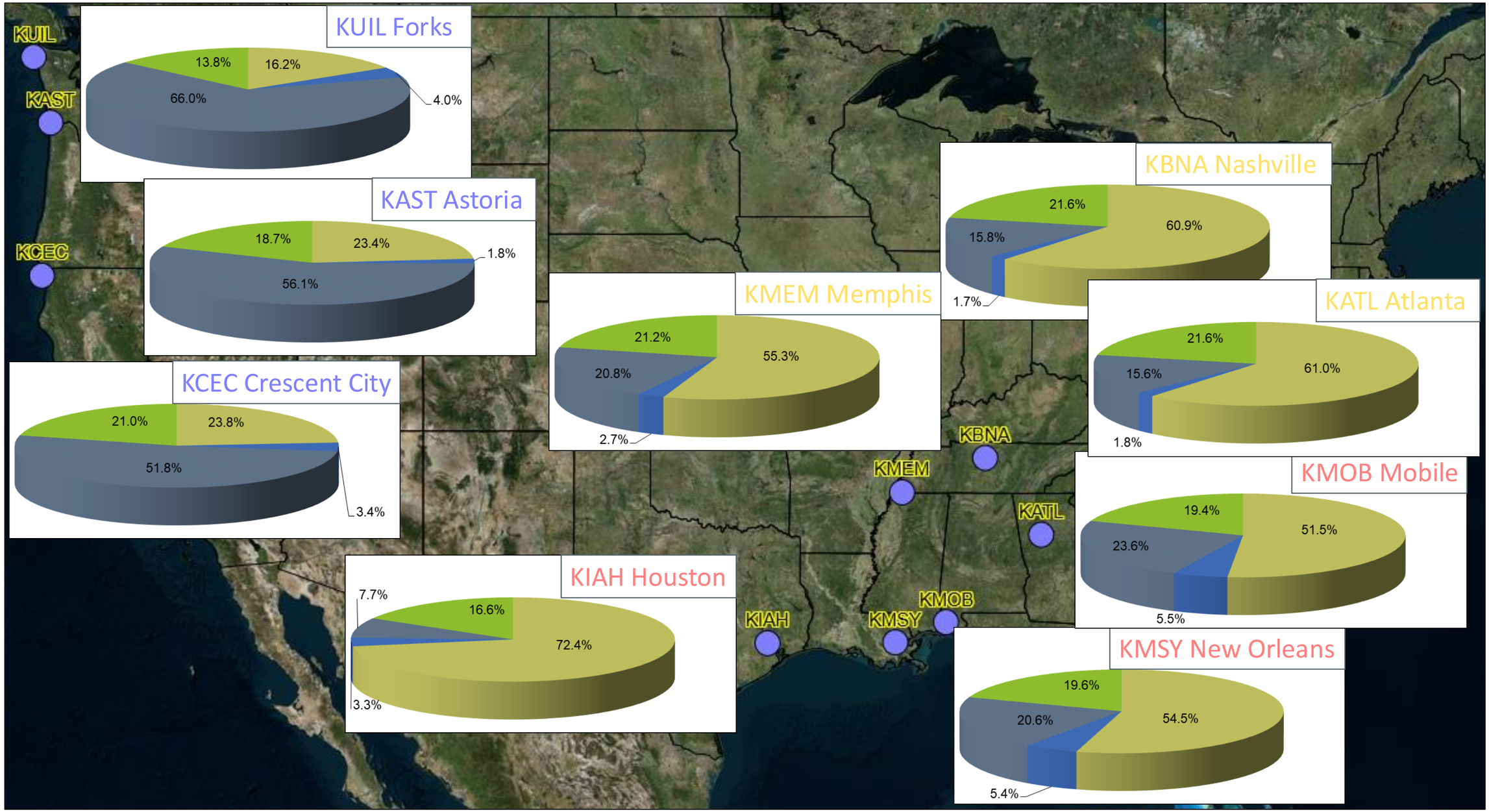


The Wet Places

	ET
min	16%
avg	47%
max	72%

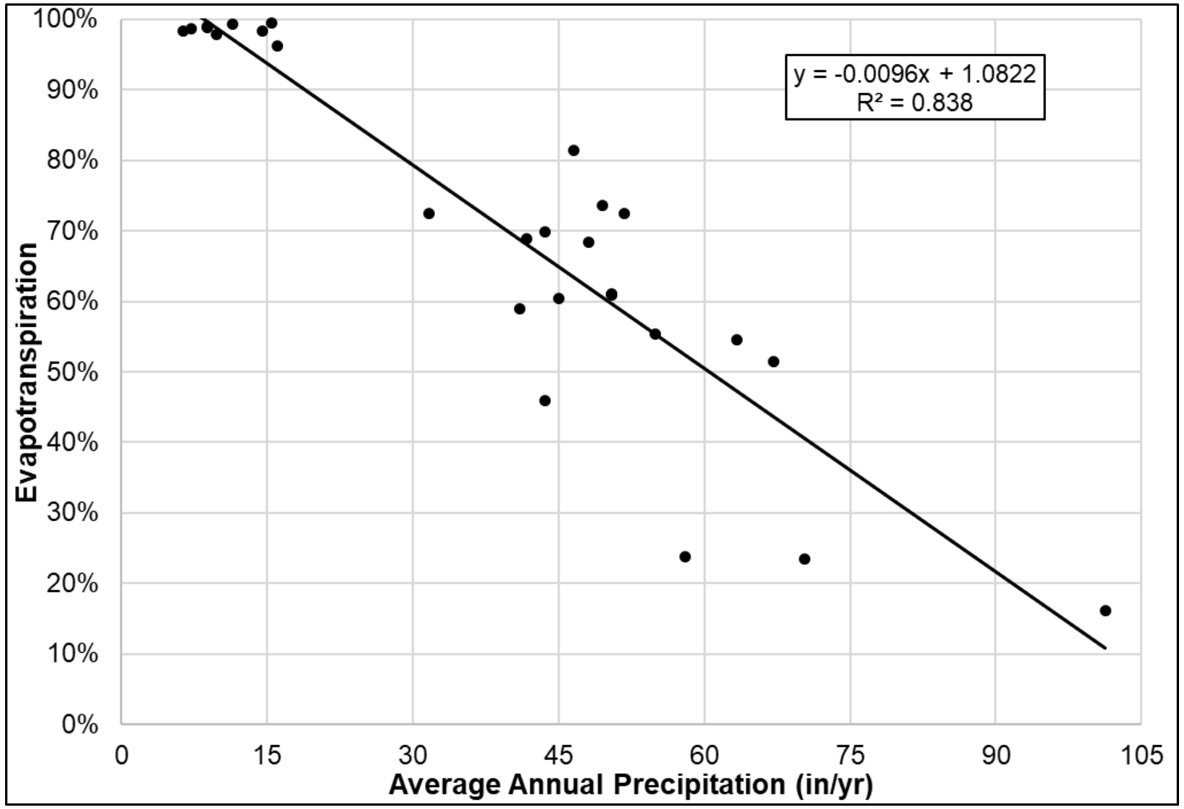
ET
Runoff
Interflow
Seepage

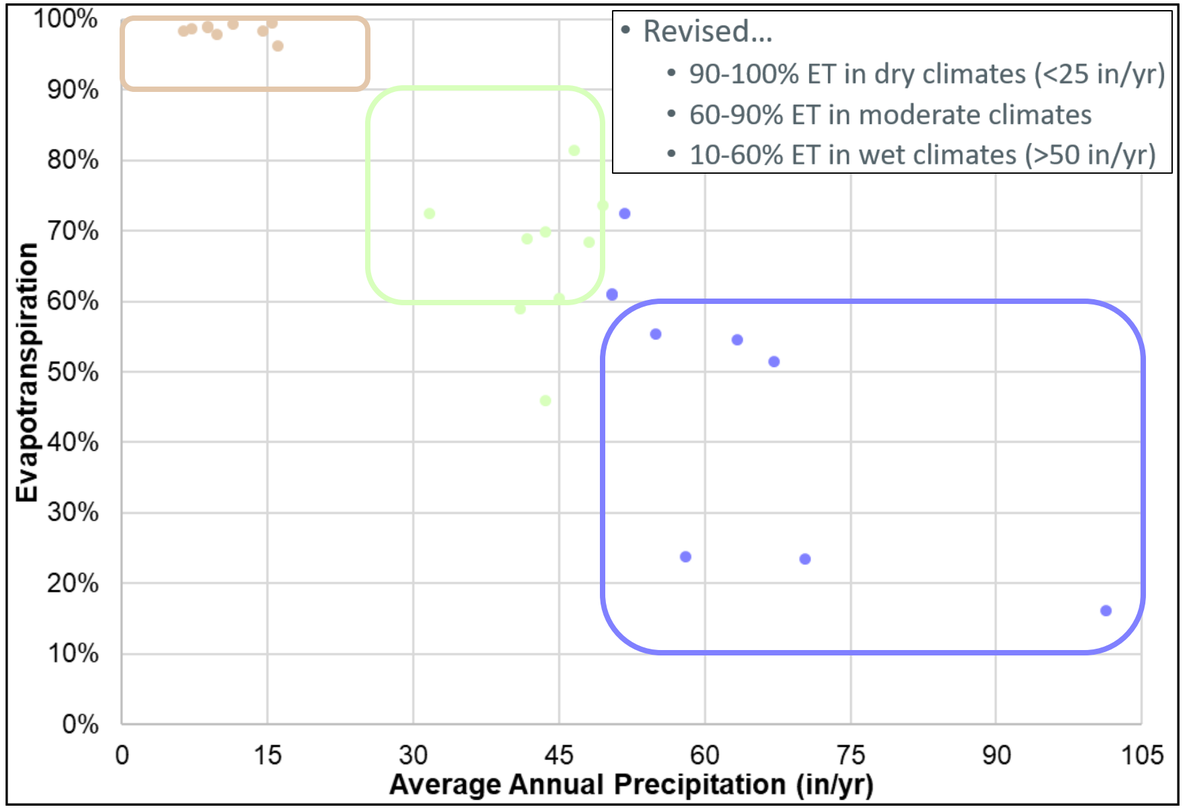
Cold (<55°F)
Temperate (55-65°F)
Hot (>65°F)



the application // correlation attempt #1

- Analytical: strong linear association – more rain means less ET
- Heuristical: not the narrow bands I was hoping for – rule of thumb needs work





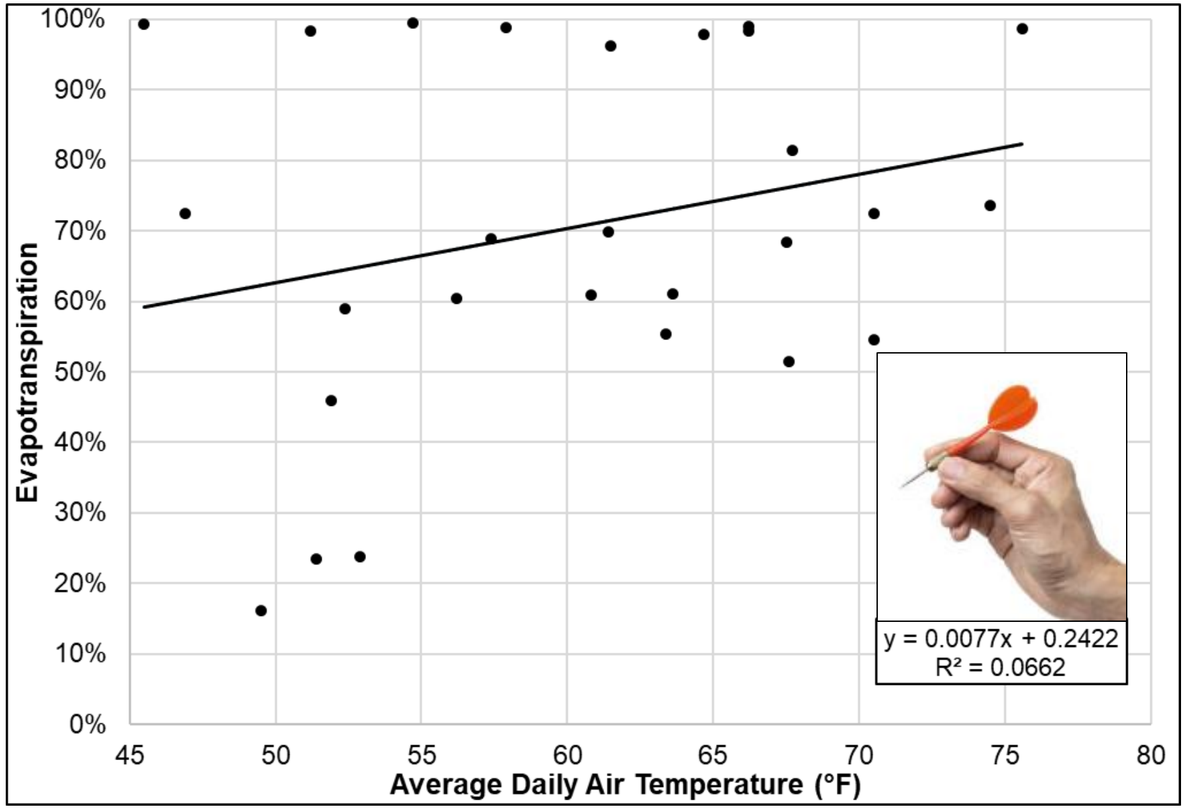
the application // correlation attempt #2

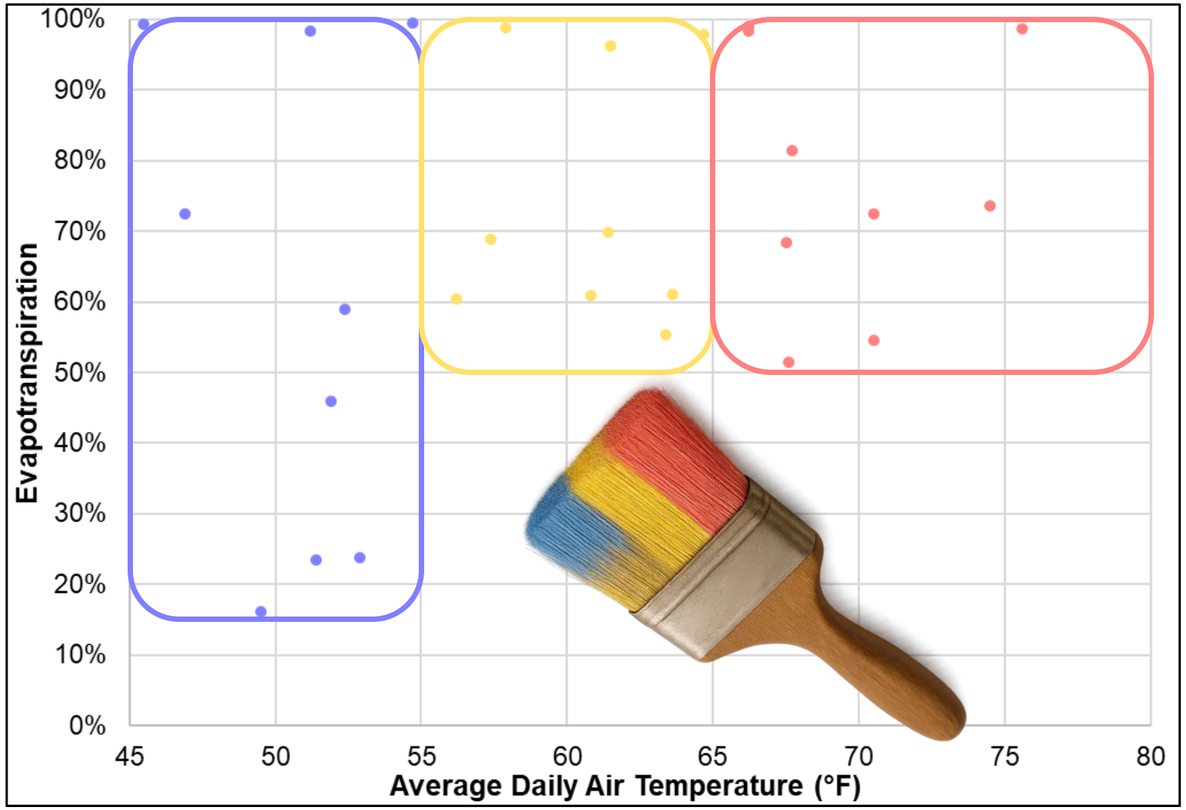
AI alert

CHI

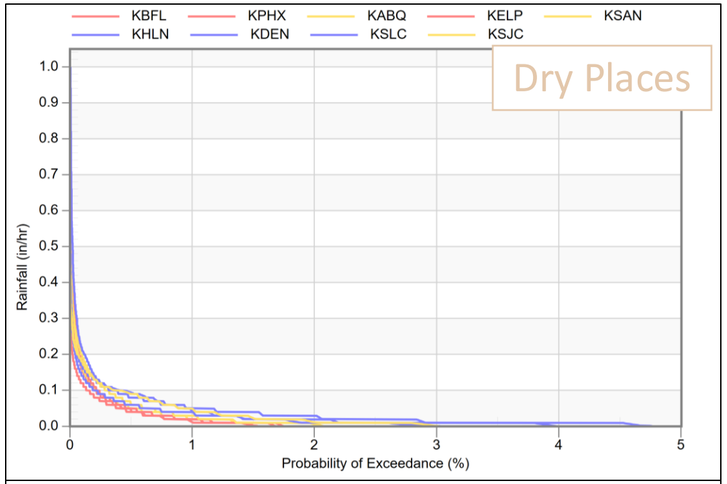
[aside] can I trust my co-pilot to drive a car when it can't tell compass directions?

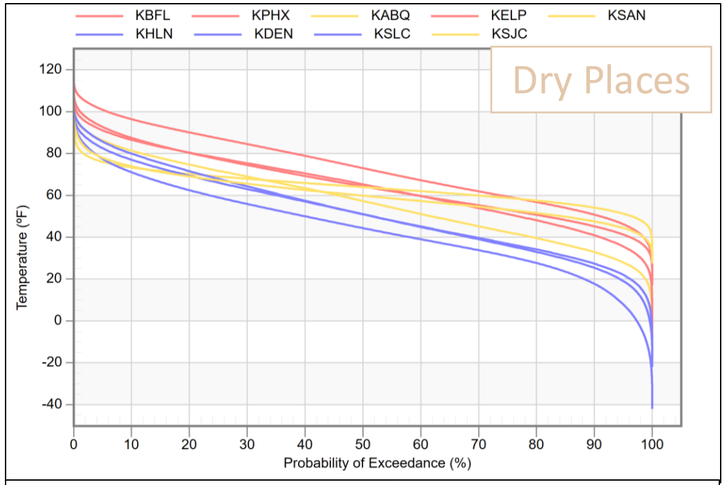
- Analytical: very weak linear association – I guess I expected more
- Heuristical: no rules of thumb here, just wide expectation bands

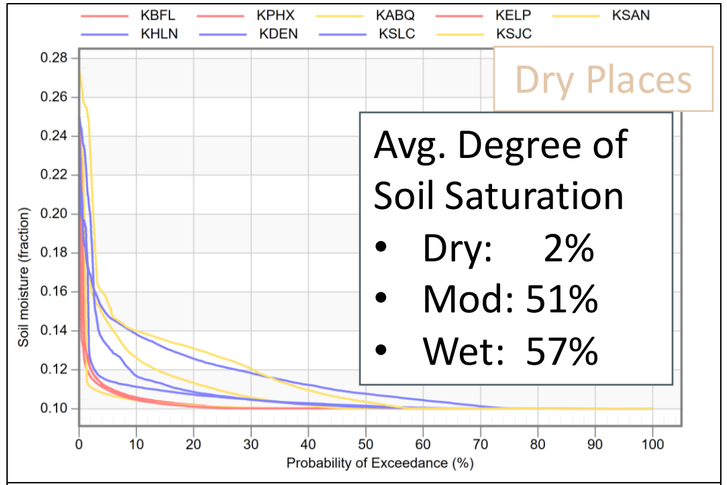




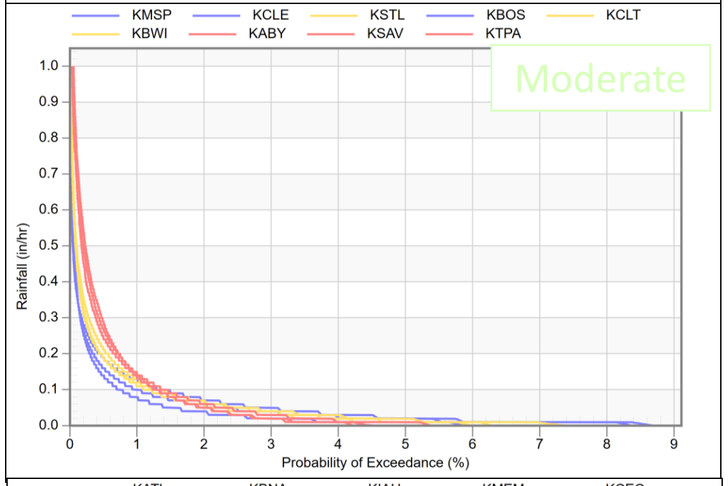
06:30

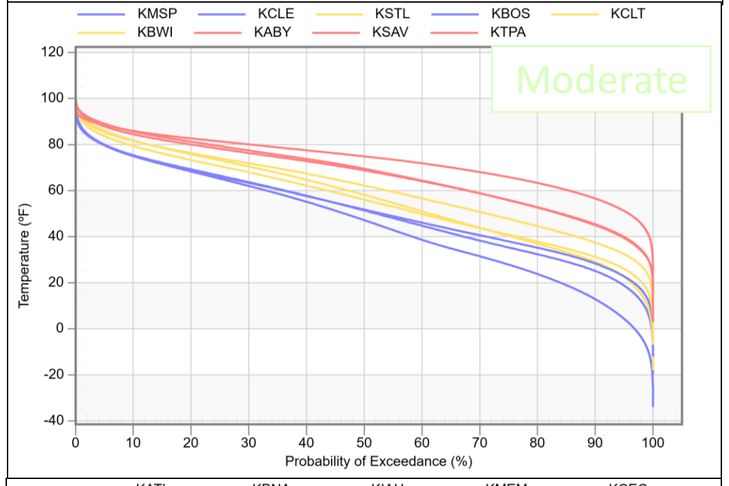


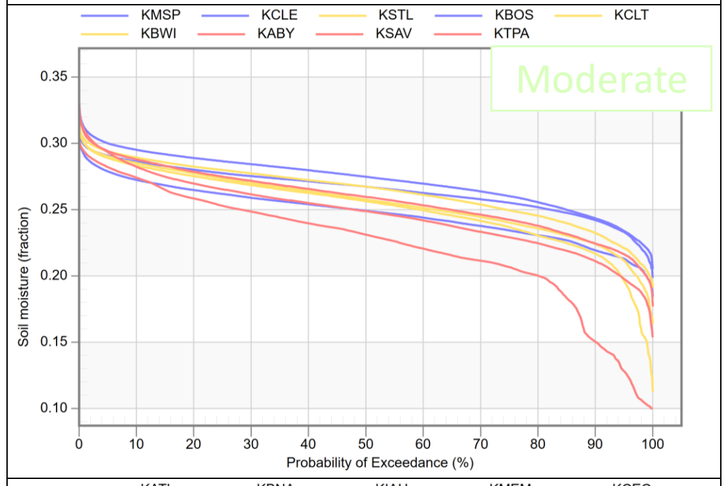


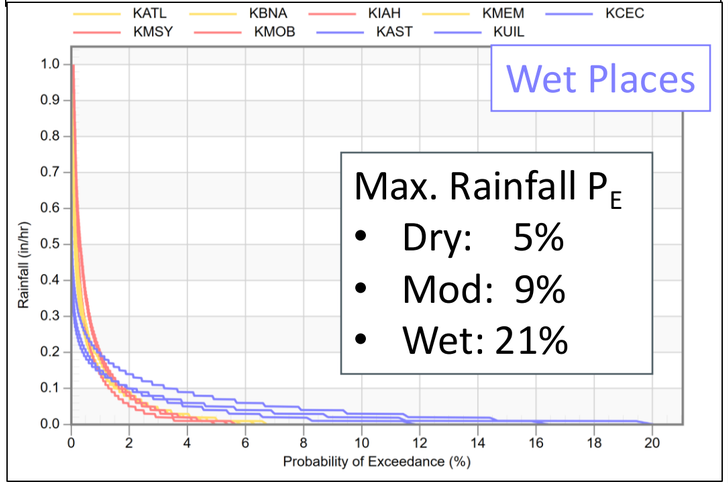


Avg. Degree of Soil Saturation
- Dry: 2%
- Mod: 51%
- Wet: 57%

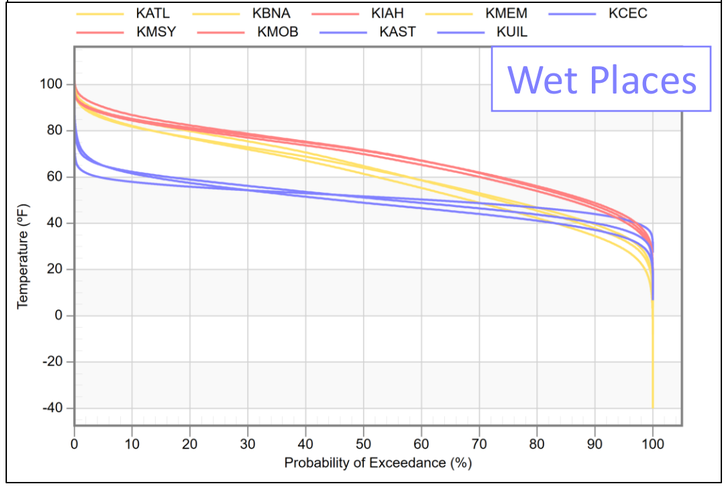


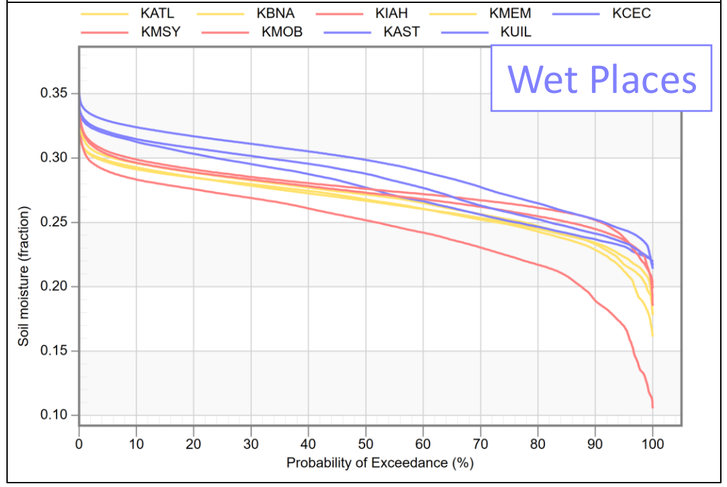






Max. Rainfall P_E
- Dry: 5%
- Mod: 9%
- Wet: 21%





Degree of Saturation for sandy loam soil
- η (θ=0.4): 100%
- fc (θ=0.2): 33%
- wp (θ=0.1): 0%

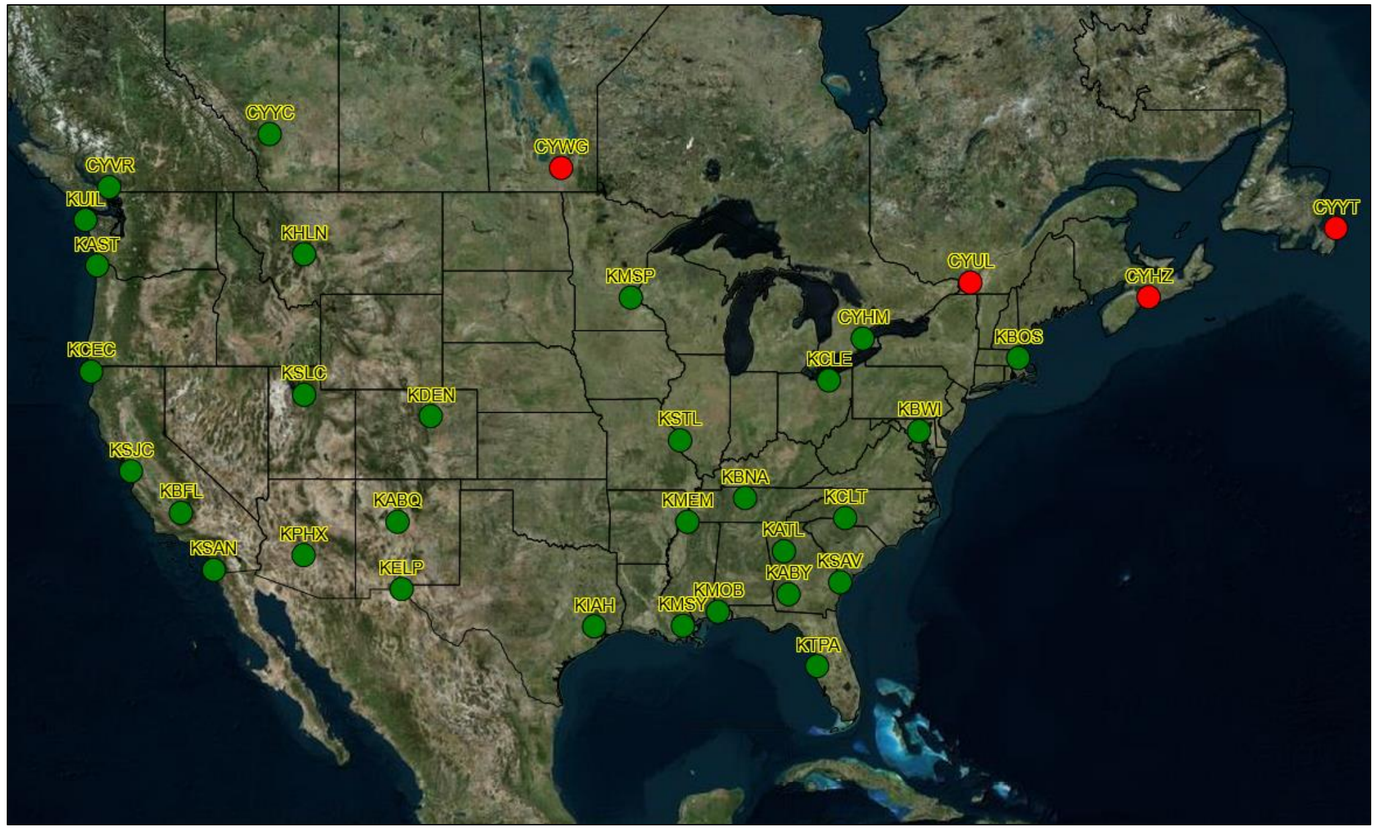
Dry (<25 in)
Moderate (25-50 in)
Wet (>50 in)

Cold (<55°F)
Temperate (55-65°F)
Hot (>65°F)

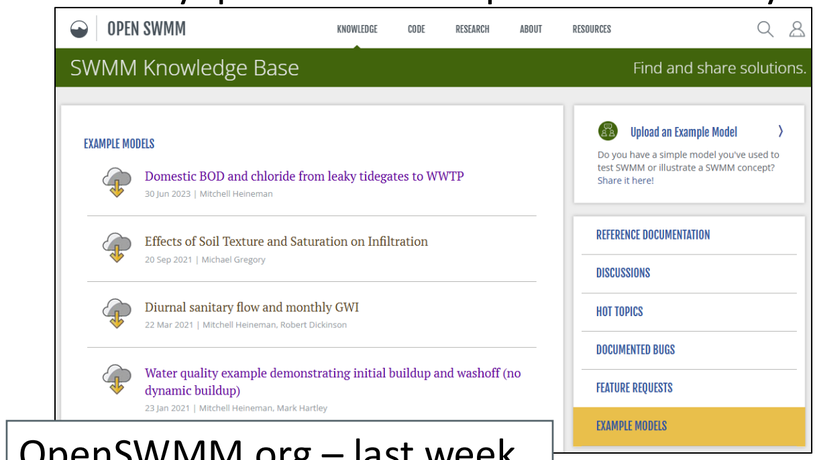
05:00

the offer // explained

- Imagined questions from the audience:
  1. “where’s the Canadian content?”
  2. “OK that sounds nice (and is very colorful) – but how does it help me?”
- Response 1: I’m working on it
- Response 2: I’ve worked on that



Been awfully quiet with Example Models lately…



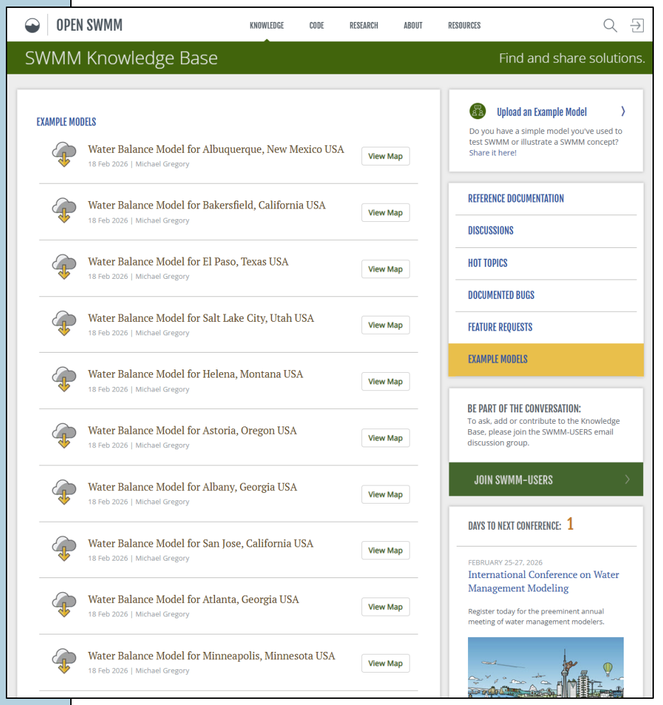
OpenSWMM.org – last week

03:00

the offer // exampled

- Check out OpenSWMM.org this week…

www.openswmm.org/SWMMExamples



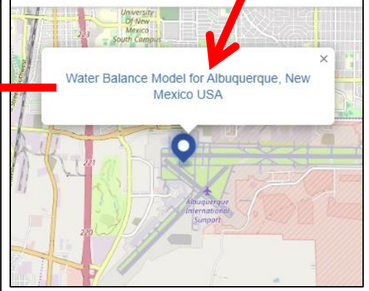
the offer // exampled in Albuquerque

SWMM Knowledge Base

EXAMPLE MODELS

Water Balance Model for Albuquerque, New Mexico USA
18 Feb 2026 | Michael Gregory
View Map

OPEN SWMM



Back to Map | GEOREFERENCED EXAMPLE MODEL | 18-Feb-2026

Water Balance Model for Albuquerque, New Mexico USA

Michael Gregory

Background

This is an example SWMM5 model that includes local climatologic input data for long-term hydrologic simulation. It is intended to provide a practical resource for modelers who are interested in comparative water balance modeling across diverse climate regions. The model represents two hydrologic response units (i.e., impervious and pervious surface cover) to evaluate the long-term average annual water balance. Model hydrology includes both groundwater and snowmelt processes and the water budget components include evapotranspiration, runoff, infiltration, and groundwater fluxes over a multi-year simulation period.

Climatologic inputs include hourly precipitation and daily temperature records from the local airport weather station, along with monthly average wind speeds (from the local 1990-2020 climate normals), and site geographic parameters (elevation, latitude, and longitude relative to the standard meridian). Climate datasets are derived from publicly available datasets provided by the U.S. National Oceanic and Atmospheric Administration (NOAA) or the U.S. Environmental Protection Agency's National Stormwater Calculator (SWC).

The model applies the Green-Ampt infiltration method for sandy loam soils, simulates snow accumulation and melt, and incorporates a shallow groundwater aquifer beneath the pervious subcatchment. A common set of groundwater/aquifer properties is applied to the pervious subcatchment, with stratigraphic elevation parameters aligned to the vertical configuration of the hydraulic network. Seasonal variability is represented through monthly adjustment factors for pervious depression storage, surface roughness, and saturated hydraulic conductivity.

Model results were analyzed by apportioning the various hydrology components in the pervious subcatchment, and determining a composite water balance, expressed as a percentage of the average annual precipitation, for the following:

- Evapotranspiration (ET) from both the surface and subsurface (groundwater) hydrology layers;
- Surface runoff;
- Shallow interflow from groundwater; and
- Seepage (deep percolation) from groundwater.

The water balance confirms the average annual evapotranspiration rate is consistent with regional expectations, namely:

- 90-100% ET in dry climates (<15 in/yr precipitation);
- 50-70% ET in moderate climates; and
- 15-25% ET in wet climates (>75 in/yr precipitation).

This downloadable model package includes the SWMM5 input file and associated climate data needed to reproduce the analysis using the EPA SWMM5 engine. Users can review hydrologic parameters, climatology settings, groundwater responses, and water balance summaries to better understand how climate, land cover, and soil properties influence long-term hydrology.

Download

This model represents hydrology at the Albuquerque International Sunport (KABQ). Note that flow routing has been disabled to reduce the simulation time. If you would like to see hydraulic model results, check the Flow Routing process model (in the General tab under Simulation Options) and note it could take 15 minutes or more when you rerun the simulation. The download file "KABQ_Balance_1947-2013_sw52.zip" (67 MB) contains the following files:

- "KABQ_Balance_1947-2013.inp": SWMM5 input file in text format
- "KABQ_Balance_1947-2013.ini": SWMM5 settings file in text format
- "KABQ_Balance_1947-2013.rpt": SWMM5 report file in text format
- "KABQ_Balance_1947-2013.out": SWMM5 output file in binary format
- "AlbuquerqueNM_DailyGHCN_Mar1931-Dec2025.txt": daily climate file from NOAA
- "AlbuquerqueNM_HourlyHPCP_Oct1947-Dec2013.txt": hourly precipitation file from NOAA

Disclaimer

The water balance model and accompanying datasets are provided "as-is" and are intended to support learning and exploration of hydrologic modeling concepts. Users should exercise independent judgment when interpreting results, as no guarantee is made regarding model performance, completeness, or suitability for specific applications.

Author

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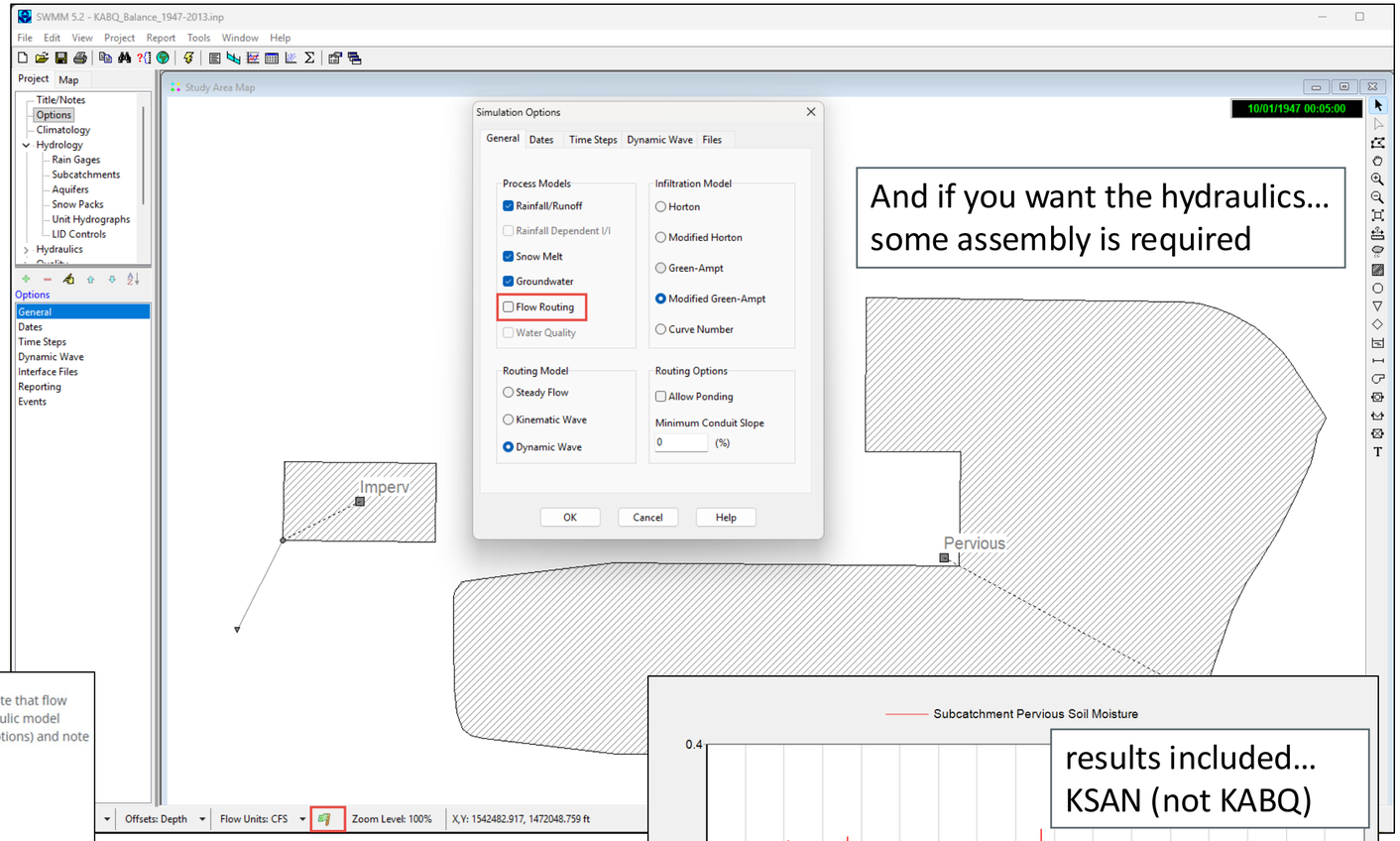
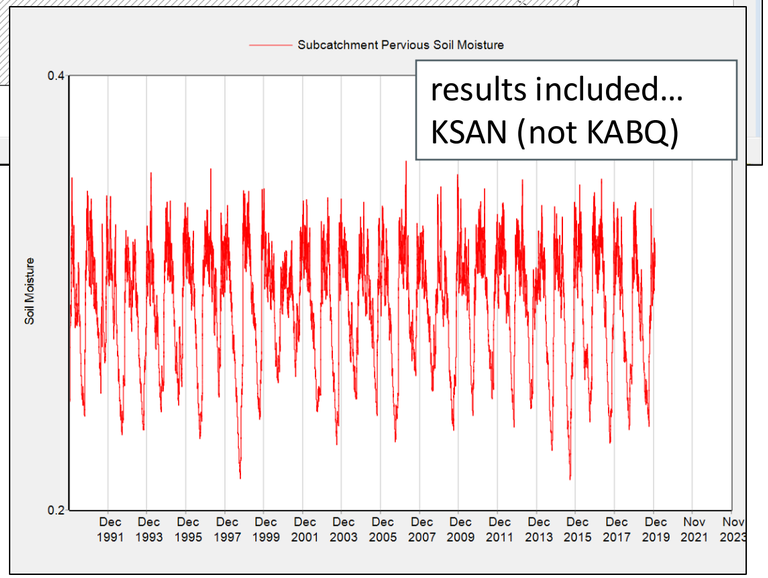
mike@chiwater.com

Download ZIP File



And if you want the hydraulics… some assembly is required



results included… KSAN (not KABQ)

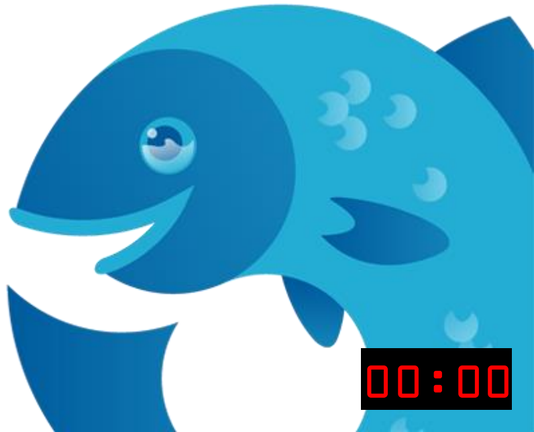
the offer // encouraged

- You too can do the same with your model!
- Today – water balance
- Tomorrow – another application: flooding, LID, snowmelt, water quality, etc.

…and final thought…

- With a systematic modeling approach, perhaps AI can be trained to build a model anywhere using online climate data

the end

CHI

Thank you for your attention!