Utilizing green technology and research to assess green roofing benefits

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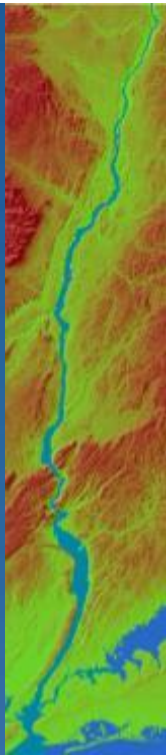


What do you want from your roof?

Long lasting watertight roof

Produce electricity

Provide natural light to the interior

Productivity

Save energy

Aesthetically pleasing outdoor space

Collect rainwater for reuse

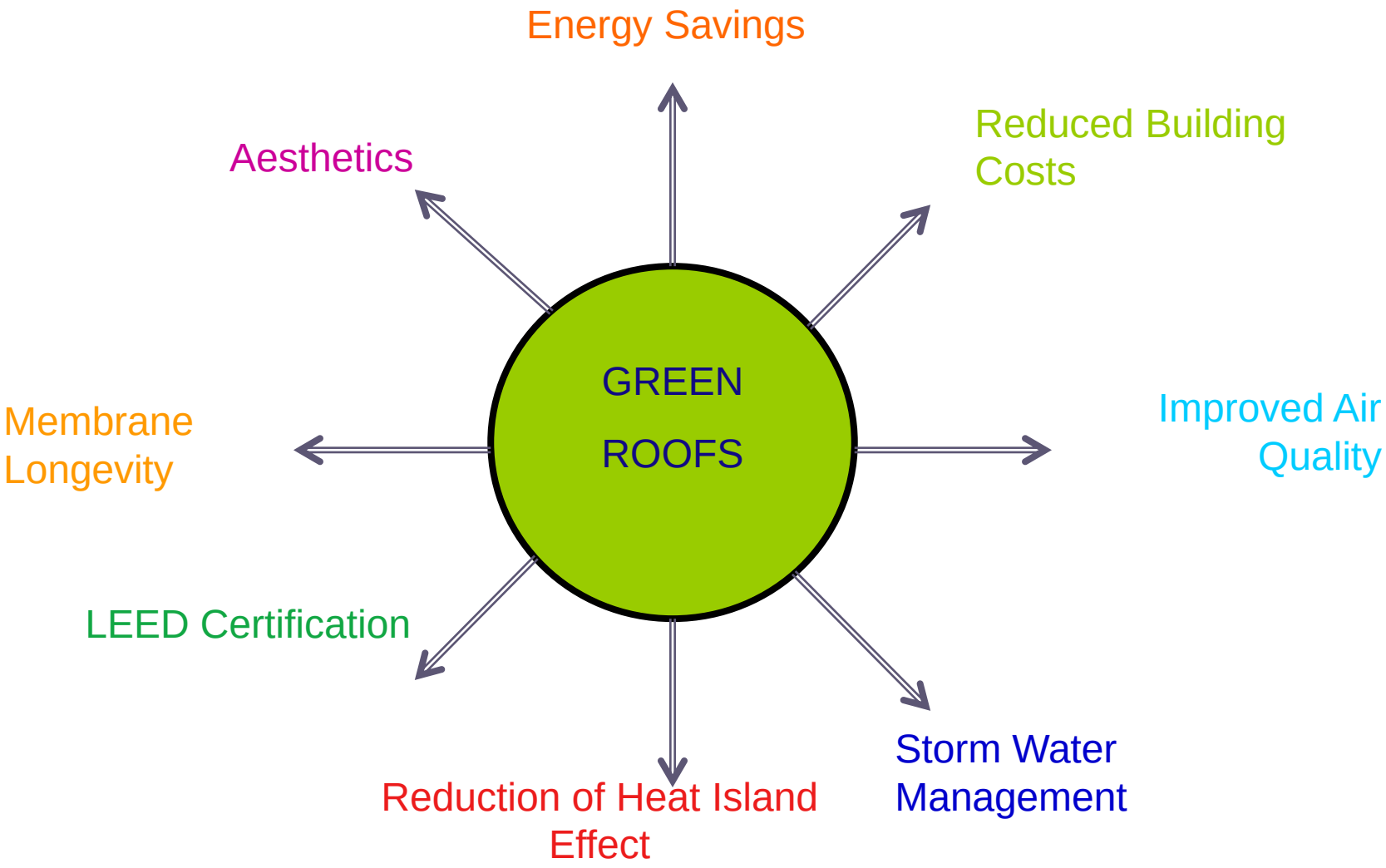
Manage stormwater

USPS Sustainability Goals

- Based on the latest published USPS Sustainability Report:

- All facilities have implemented energy saving technologies
- * Energy-efficient lighting & controls
- * Mechanical system control upgrades
- * Energy-efficient chillers
- * Air compressors

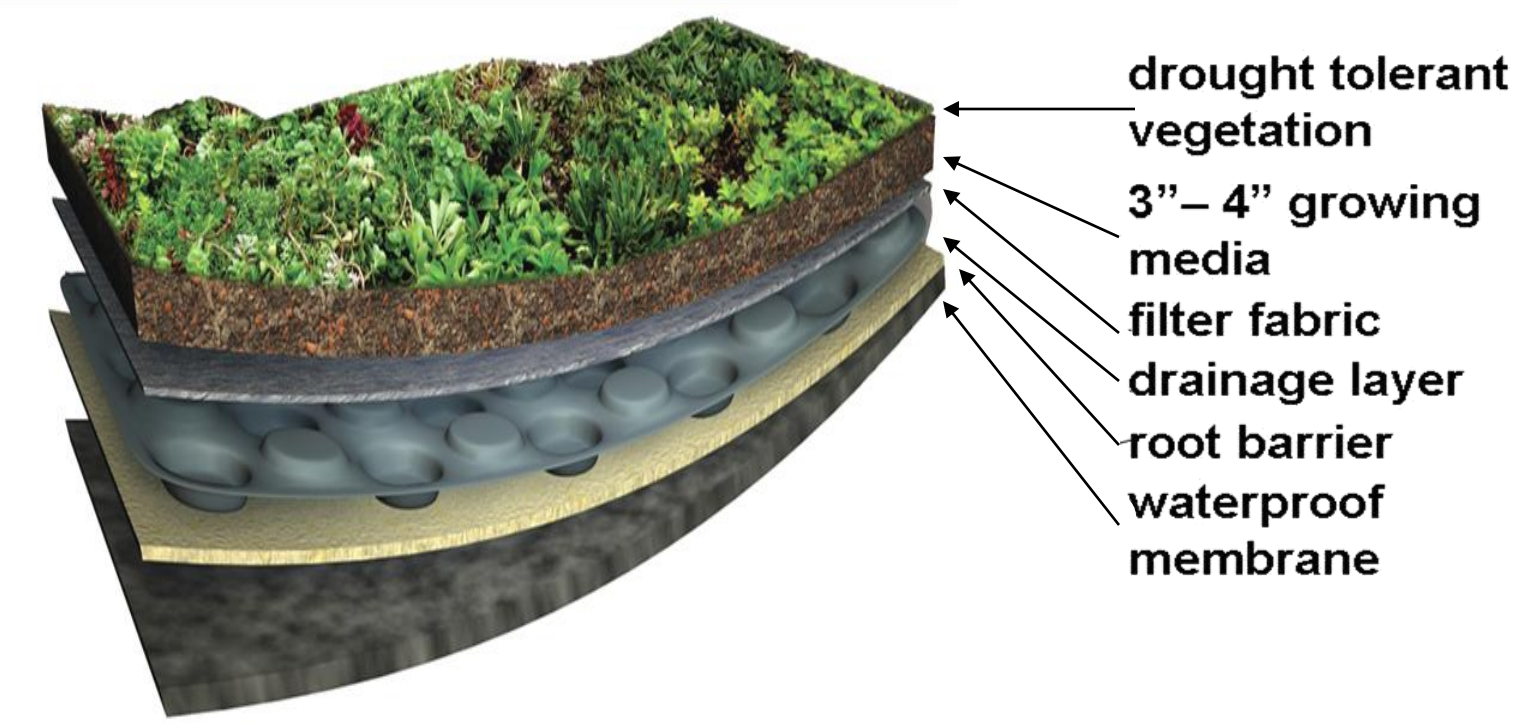
Green Roofs Lead to….

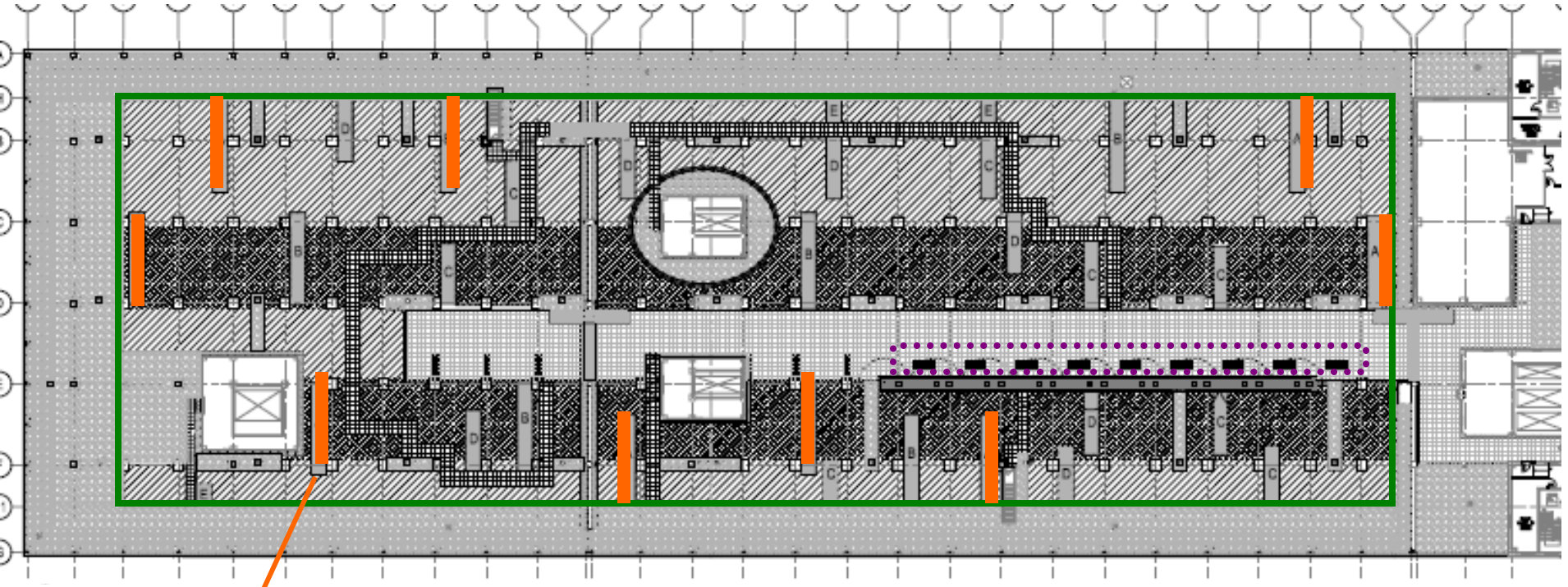


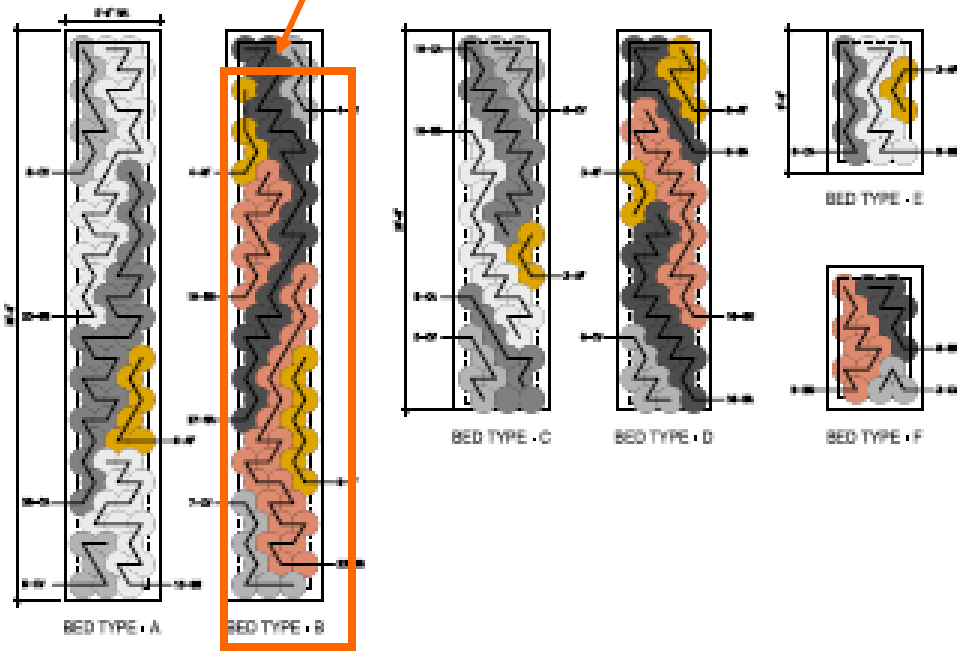
Why a Green Roof in NYC?

- **Reduces the urban heat island effect & ambient air temperature**
- **Reduces storm water run-off and the likelihood of sewage overflow**
- **Energy savings due to lower cooling expenses**
- **Community green space**

Typical Green Roof Construction







65,000 vegetated area
Bermed areas have 8” to plant grasses and perennials

Construction and Site Issues


TectaAmerica Corp.


TectaAmerica Corp.

USPS, Morgan 9th Ave NYC

July 2009

Green Roof Installation Complete

Green Roof at USPS-Morgan facility

Green Roof Installation Complete

Postal to Performance


TectaAmerica Corp.

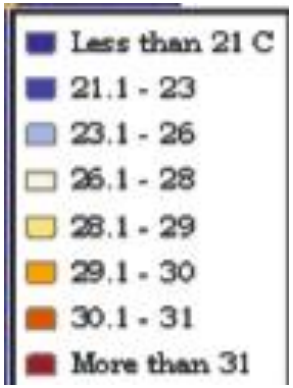
Four Seasons Green Roof, Jan 2011 NYC

Columbia University Roof, Jan 2011 NYC

Overview:

- Roofs to Rivers
Public Health Aspects:
- **Water (Quantity, Quality/Pathogens)**
- **Air (Quality/Pollutants)**

- Heat Island Effect



- BMP for CSOs

- Historical Metabolism
- **CO_2 concentrations in NYC**
- **External Controlling Factors**
- **Internal Controlling Factors**
- **Implications**

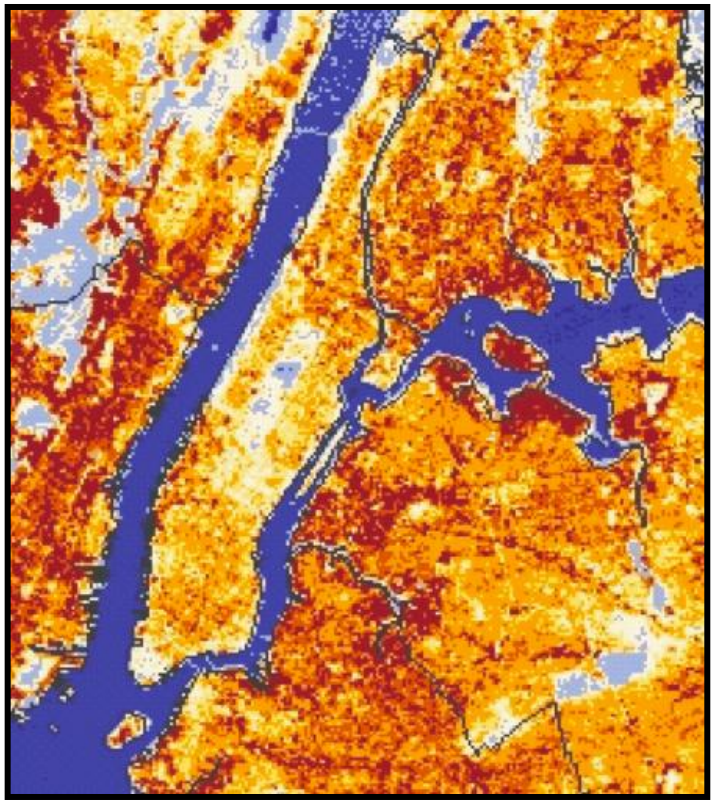
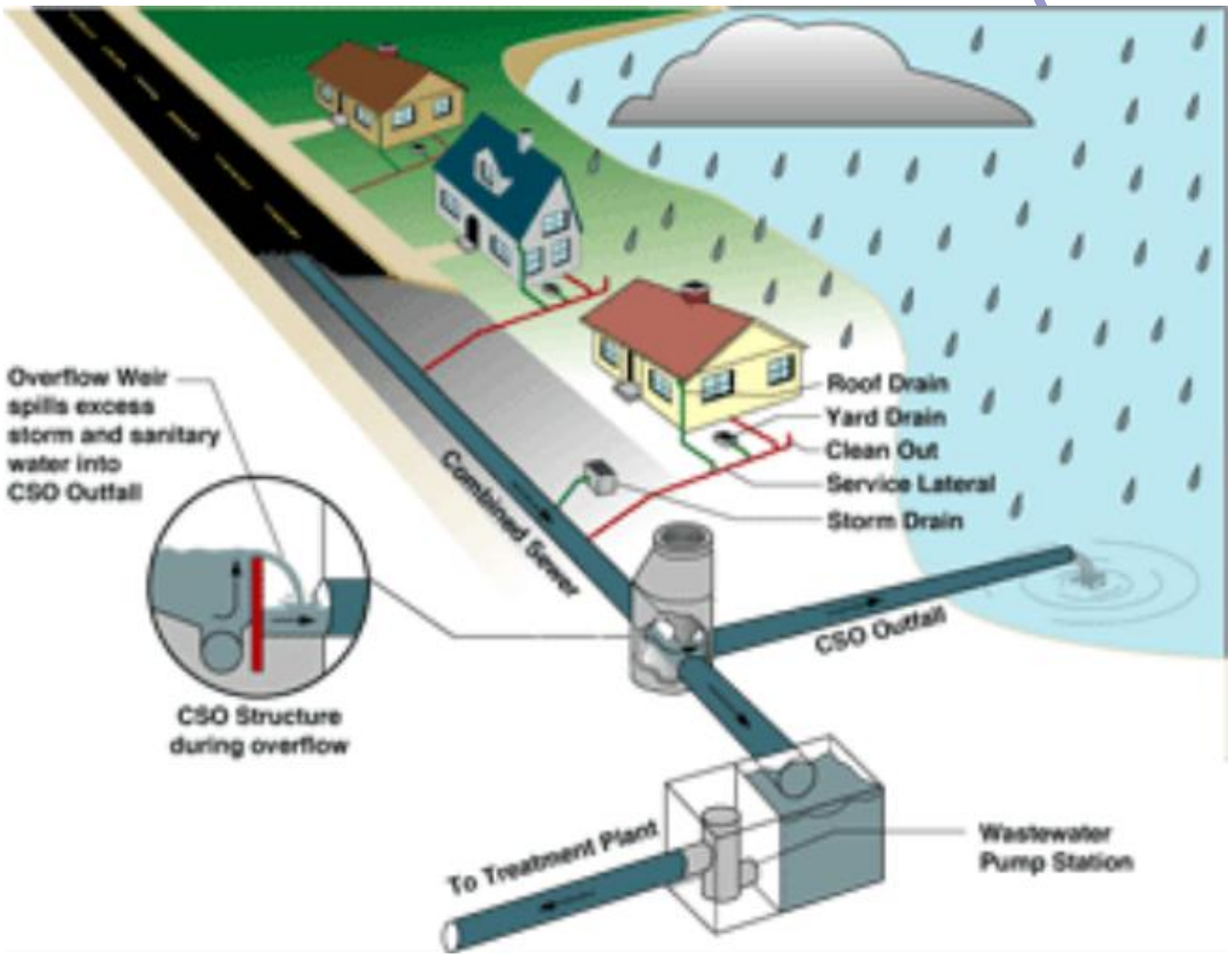
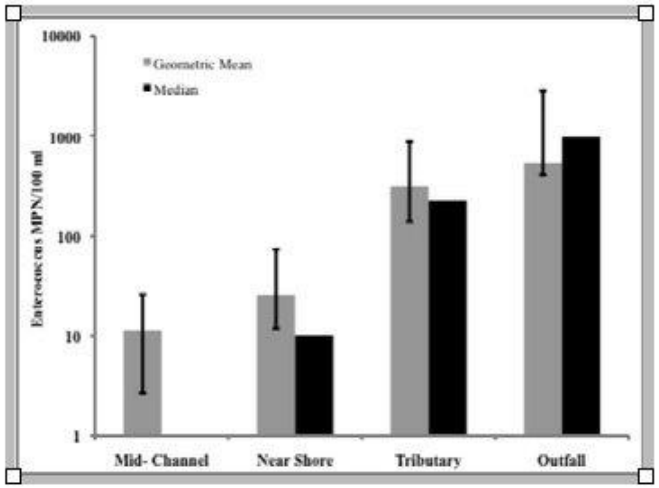


Table adapted from Rosenzweig et al. 2006

Combined Sewer Overflows (CSOs)



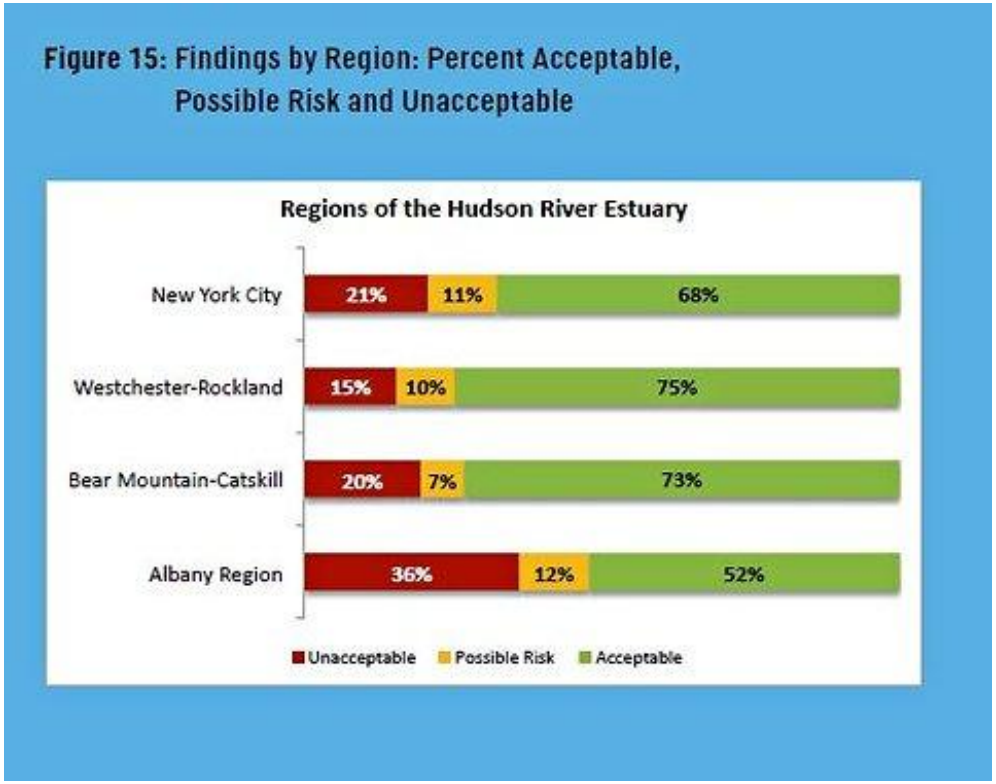
Cross-river **pathogens** variability



Enterococcus geometric mean and median for different habitat categories in the lower HRE

July 2011 Explosion and Waste Release in Hudson

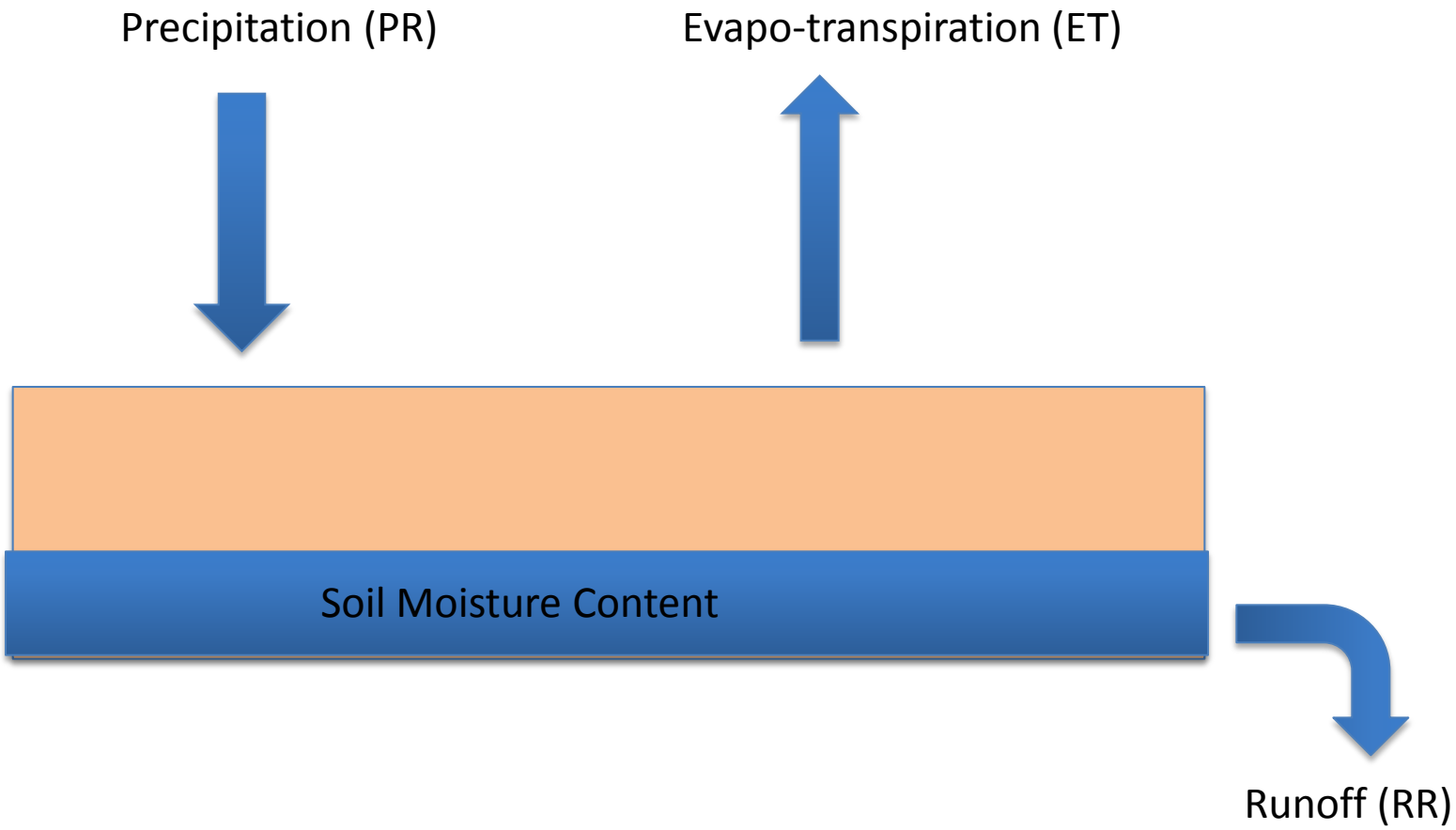
"Millions of Gallons of Sewage Spill Into the City's Waterways Every Time It Rains Half an Inch"

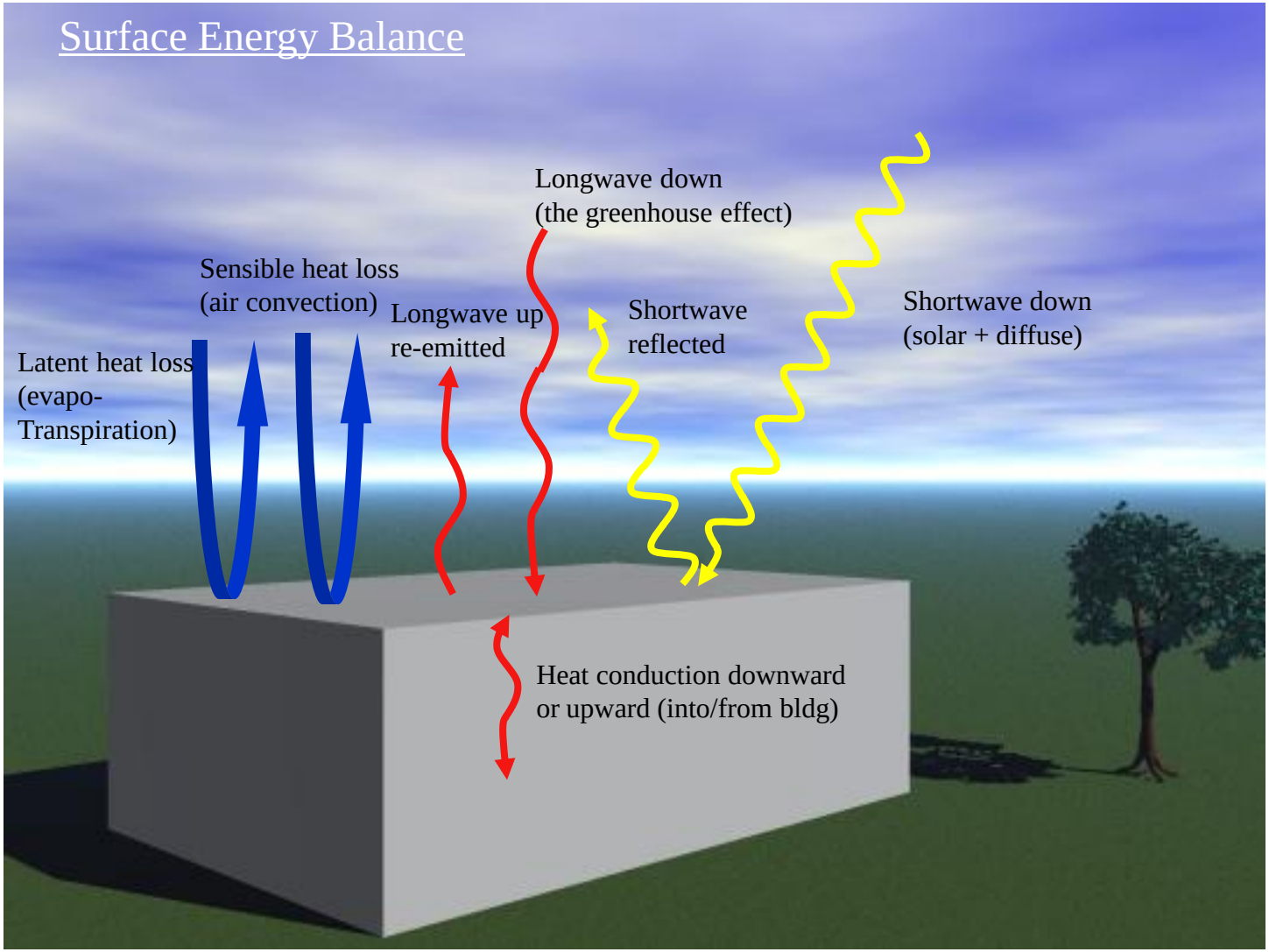


Some Terminology

- **Retention** – a quantity of water that never runs off from system, (**evapo-transpired**, **latent heat**).
- **Detention** – water that is temporarily stored in system but ultimately released as runoff.
- **Evapo-transpiration (ET)** – water vapor released to atmosphere as either direct evaporation or plant transpiration.
- **Latent Heat** – heat loss from a surface in the form of phase change of liquid water to vapor, equivalent to ET.

Roof Water Budget




Surface Energy Balance
Longwave down
(the greenhouse effect)
Sensible heat loss
(air convection)
Longwave up
re-emitted
Shortwave
reflected
Shortwave down
(solar + diffuse)
Latent heat loss
(evapo-
Transpiration)
Heat conduction downward
or upward (into/from bldg)

We use the integrated energy balance equation to solve for latent heat flux:

$$\int (SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow) = \int SH + \int LH + \int \text{Heat Cond Below}$$

$$+ \int \text{Internal Green Roof Energy Change Rate}$$

small over time

$$\int (SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow) \approx \int SH + \int LH + \int \text{Heat Cond Below}$$

Water (and Energy) Budget Equation

Rain = Runoff + Evaporation
+ Water Storage Change Rate

or

Evaporation = Rain – Runoff (measured)

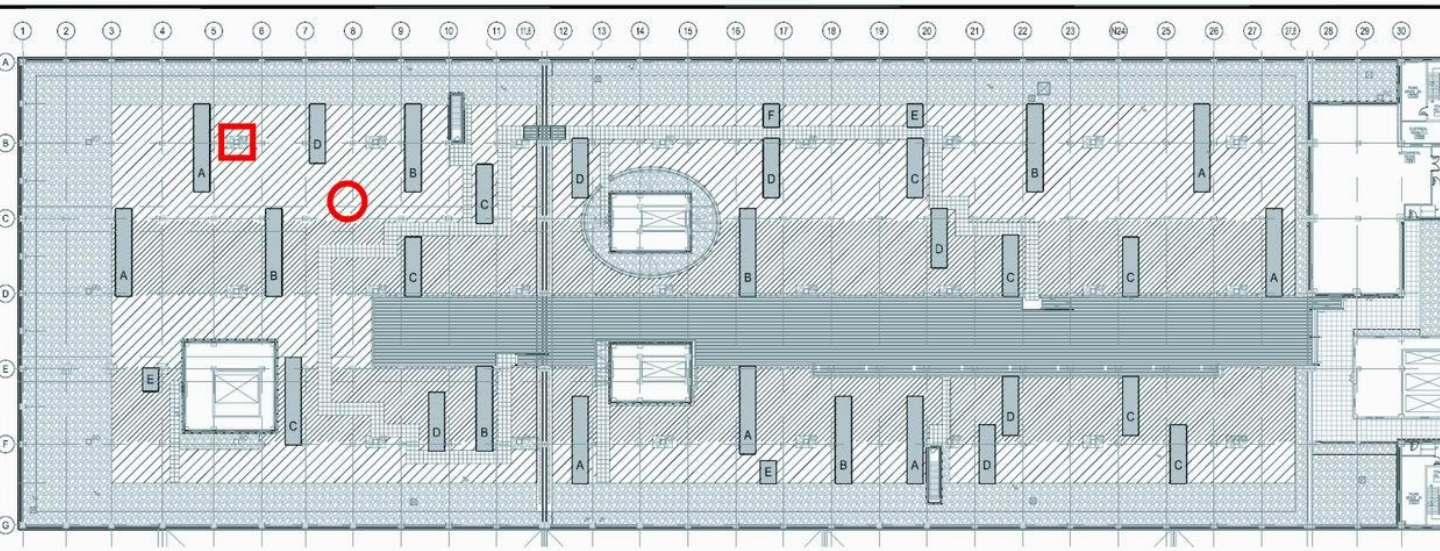
or

From Energy Equation:
Evaporation = Residual of Latent Heat Flux

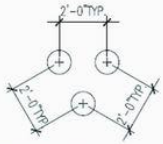
The Environmental Monitoring

- **Real-time measurements**
- **Evapotranspiration**
- **Heat Island 'Cooling'**
- **Wind Speed Forcing**
- **Relative Humidity**
- **Up/Downwelling Radiation**
- **Albedo – Radiative Reflectance and Absorption**

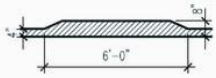
Columbia University Research:
measure evapotranspiration, sensible heating, weather, and carbon dioxide exchange; biodiversity



1 SK-1 SIXTH FLOOR ROOF - PLANTING PLAN
SCALE: 1"= 40'-0"



2 SK-1 SEDUM PLUGS SPACING DIAGRAM
SCALE: 1/4"= 1'-0"



3 SK-1 6' WD. RAISED BED
SCALE: 1/4"= 1'-0"

PLANT MATERIALS LIST

QUANTITY	BOTANICAL NAME	COMMON NAME
SEDUMS CUTTINGS + PLUGS BY PERCENTAGE		
7%	Sedum acre	Golden Moss Stonecrop
10%	Sedum album 'Coral Carpet'	White Stonecrop
7%	Sedum album micranthum 'Chlorolicum'	White Stonecrop 'Baby Tears'
10%	Sedum album 'Murale'	
5%	Sedum 'Black Jack'	'Black Jack' Stonecrop
7%	Sedum forsterianum	Rock Stonecrop
7%	Sedum grisebachii	
7%	Sedum kamtschaticum	Kamschatka Stonecrop
5%	Sedum x 'Matrona'	'Matrona' Stonecrop
7%	Sedum pluricale "Rose Carpet"	
7%	Sedum spurium 'Fuldaglut'	Two-row Stonecrop
7%	Sedum spurium 'John Creech'	'John Creech' Stonecrop
9%	Sedum spurium 'Roseum'	Two-row 'Roseum' Stonecrop
7%	Sedum sexangulare	Six-sided Stonecrop
5%	Sedum telephium	'Autumn Joy' Stonecrop
1 QT / PLUGS @ 18" O.C.		
319	Bouteloua gracilis	Blue Grama – Mosquito Grass
392	Calamagrostis acutiflora epigejos	Bushgrass
336	Sporobolus airoides	Alkali Dropseed
455	Schizachyrium scoparium	Little Bluestem
198	Achillea filipendulina	Fern-Leaf Yarrow
299	Coreopsis Verticilata 'Moonbeam'	Treadleaf Coreopsis

LEGEND

AREA OF SEDUMS CUTTINGS ONLY = 25,650 SF

AREA OF SEDUMS CUTTINGS + PLUGS = 24,400 SF

D

AREA OF 6' WIDE RAISED BED, PERENNIALS+GRASSES = 5,200 SF

TOTAL PLANTING AREA= 55,250 SQ.FT

Legend

Environmental Monitoring System

- Wind Speed/Direction
- Wind Speed
- 4 RH/T's
- 2 Solar Radiation
- 2 Photosynthetic

Weir System

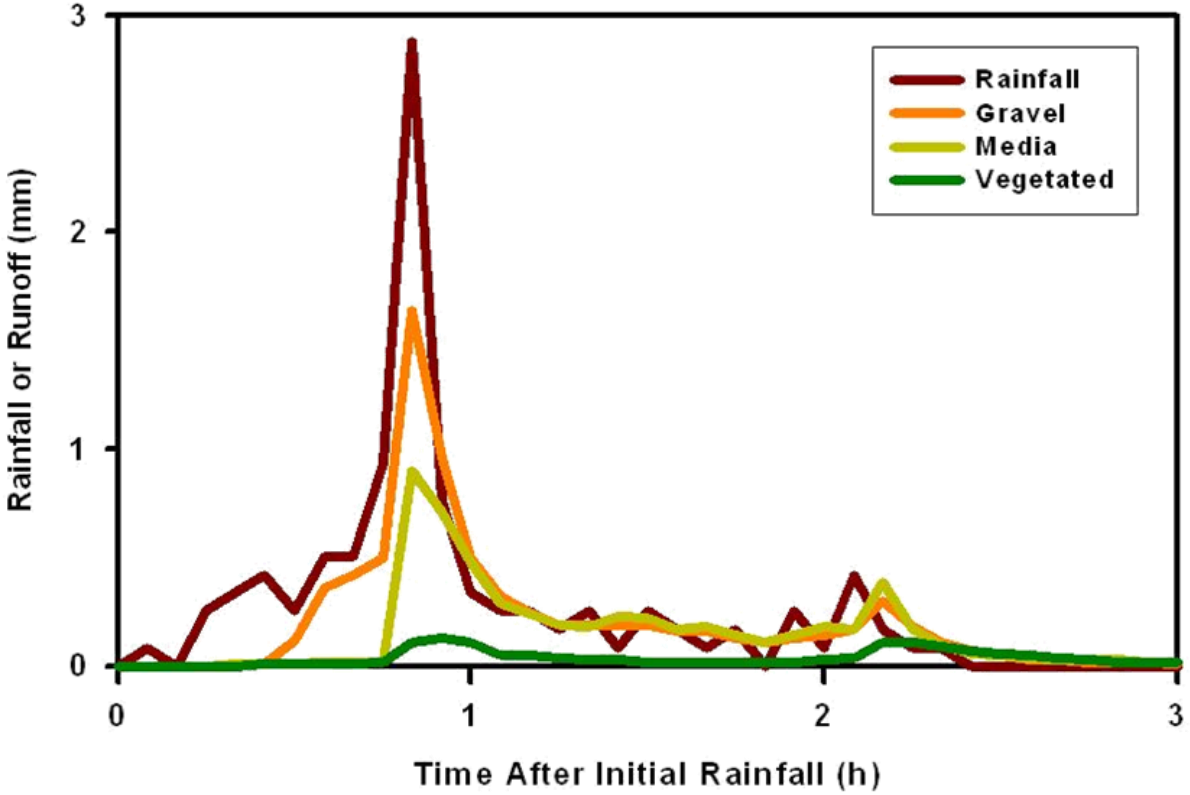
- Weir (Water Quantity)
- Conductivity
- Rain
- Soil Temperature
- Soil Moisture

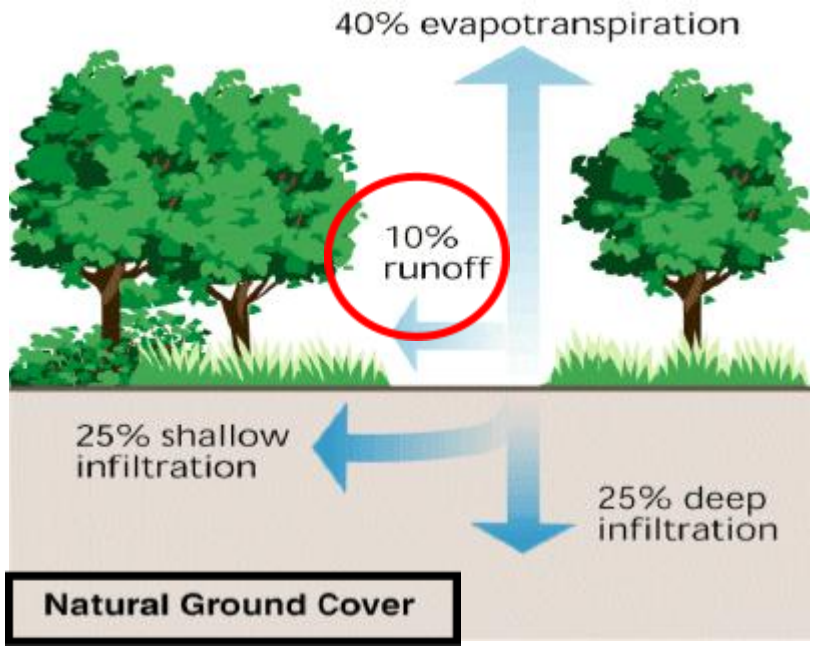
The Weir

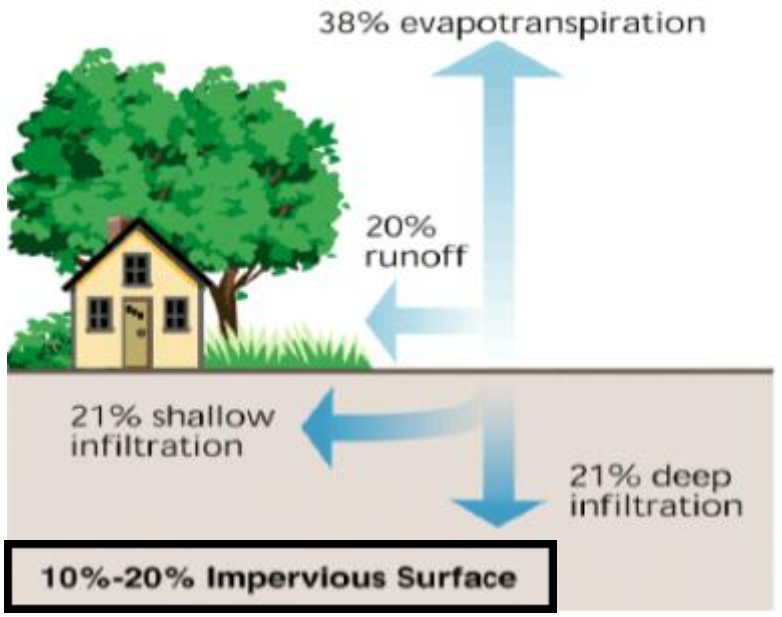
- **Real-time measurements**
- **Run-off quantity**
- **Run-off water quality**

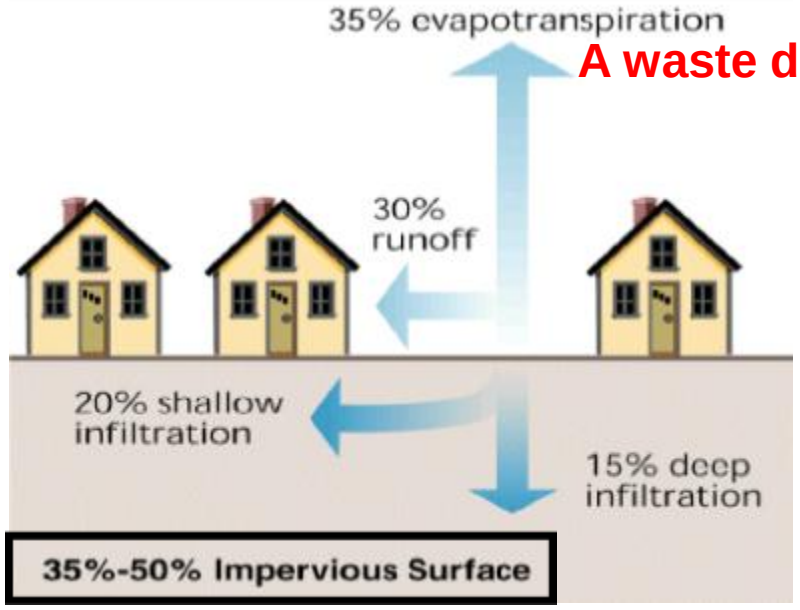
Storm Water Management

Snapshot hydrograph, 0.4” rainfall
Vegetation impacts: Reduced peak, Delayed total

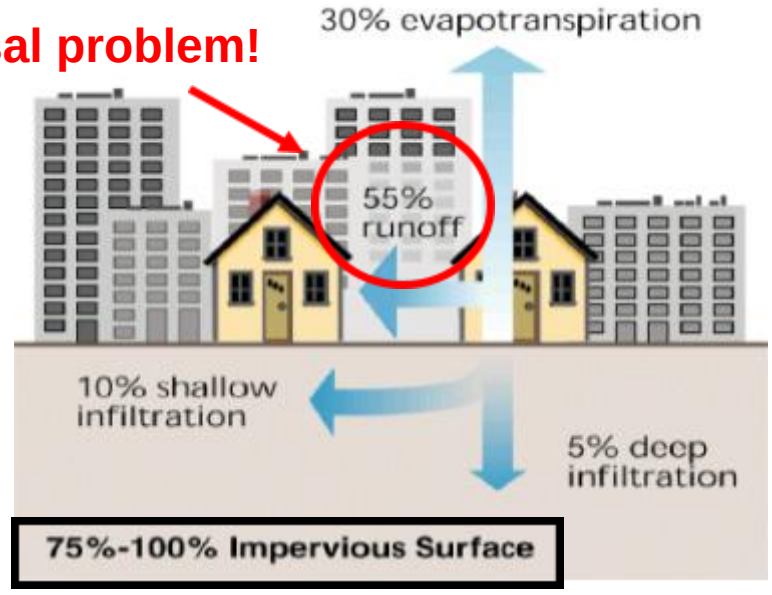








A waste disposal problem!



Images developed by the USEPA

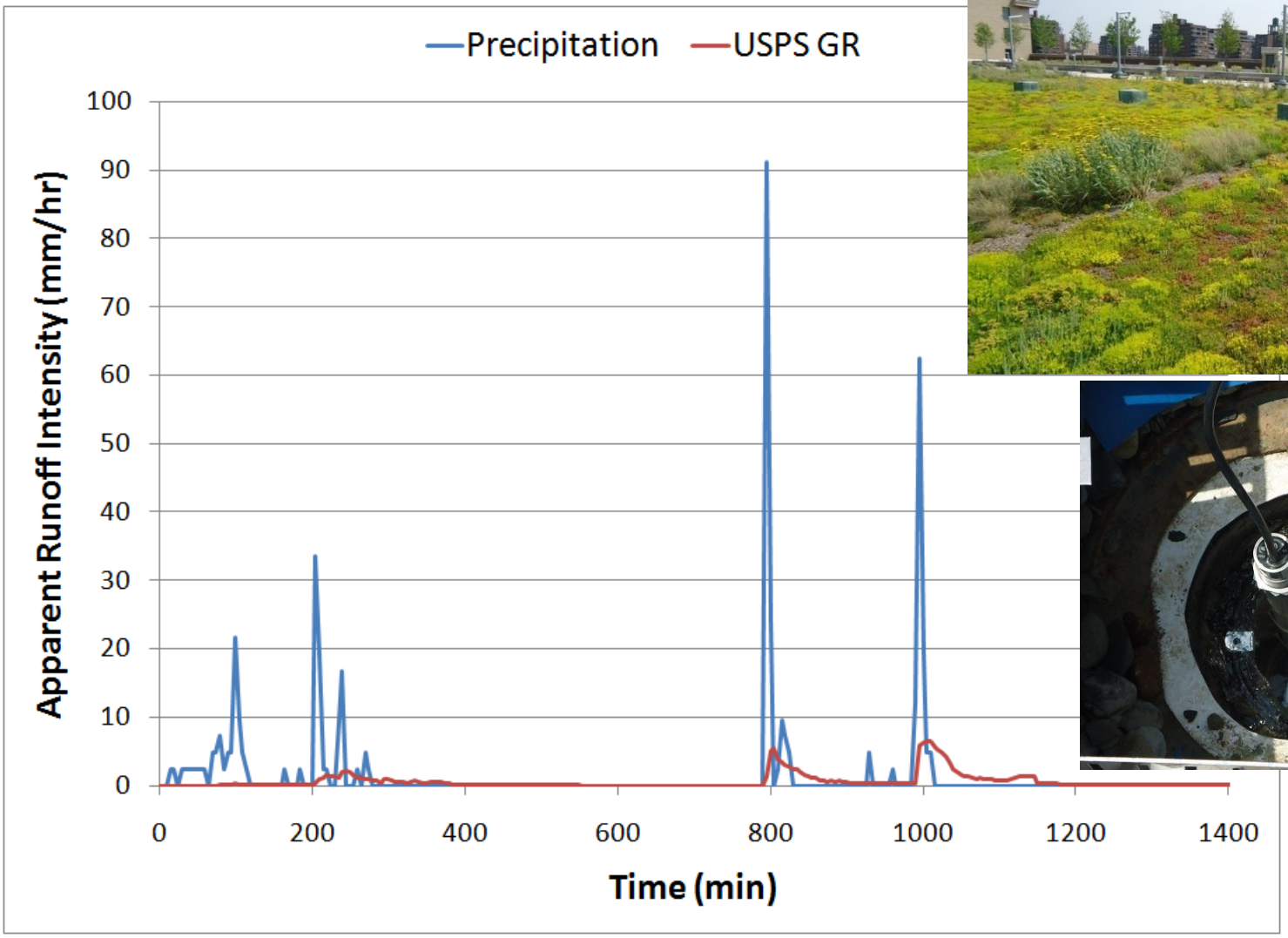
Green Roofs

Porous Pavements

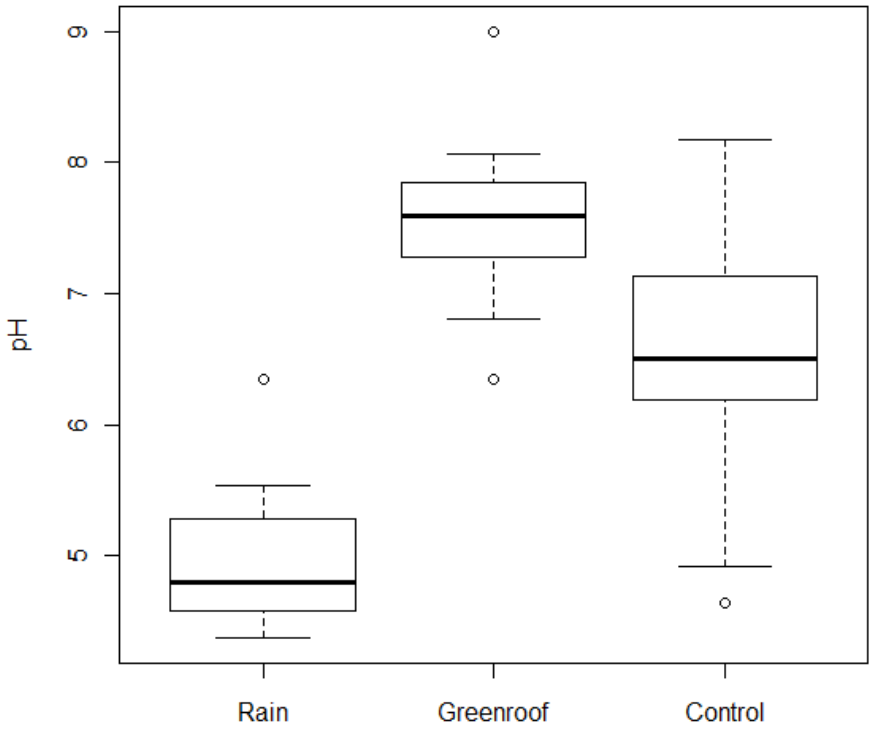
Green streets

Locations of some Columbia Green Roof Consortium monitoring sites

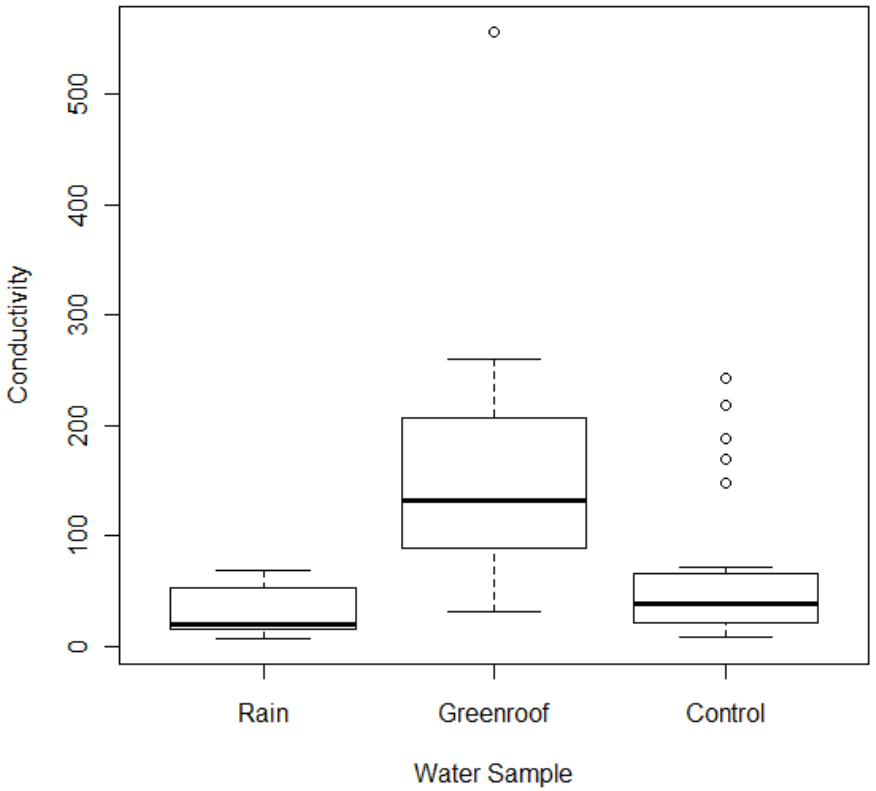
Water Quantity – USPS Green Roof



Water Quality

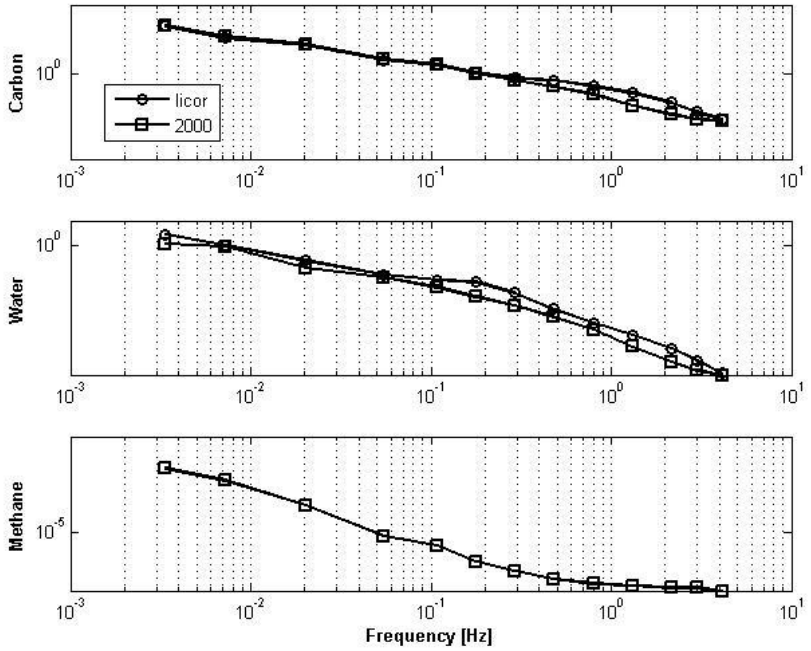


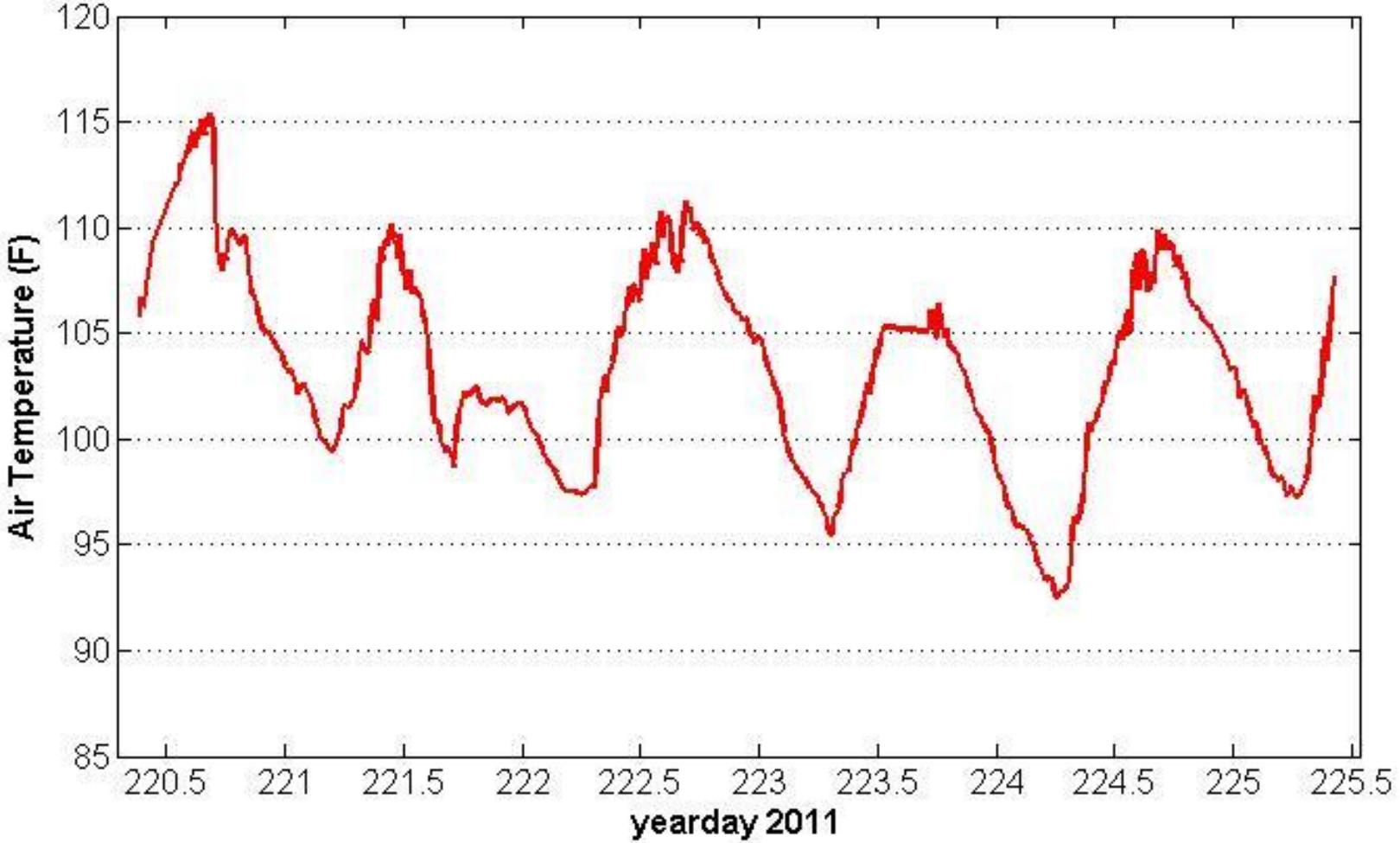
pH

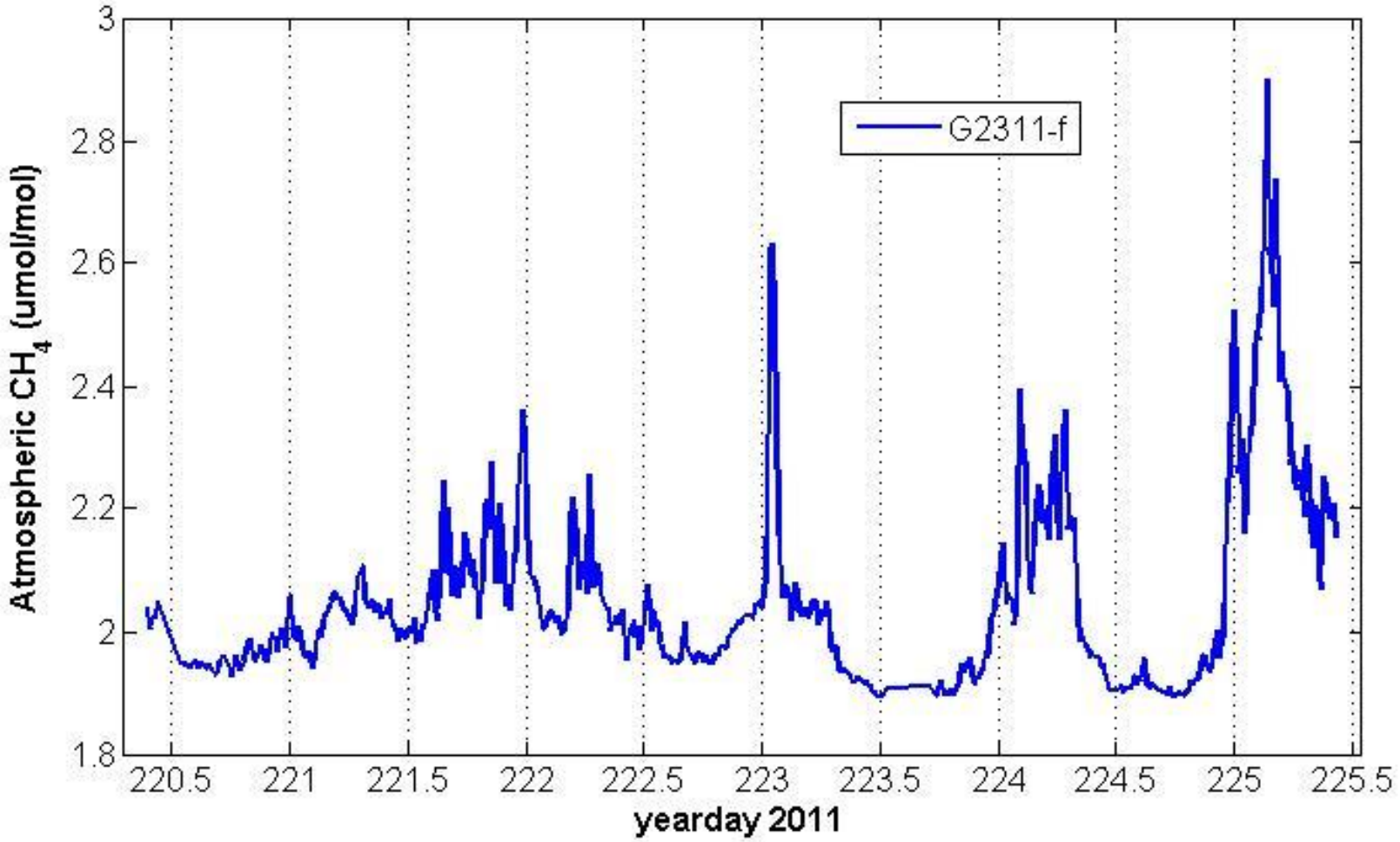


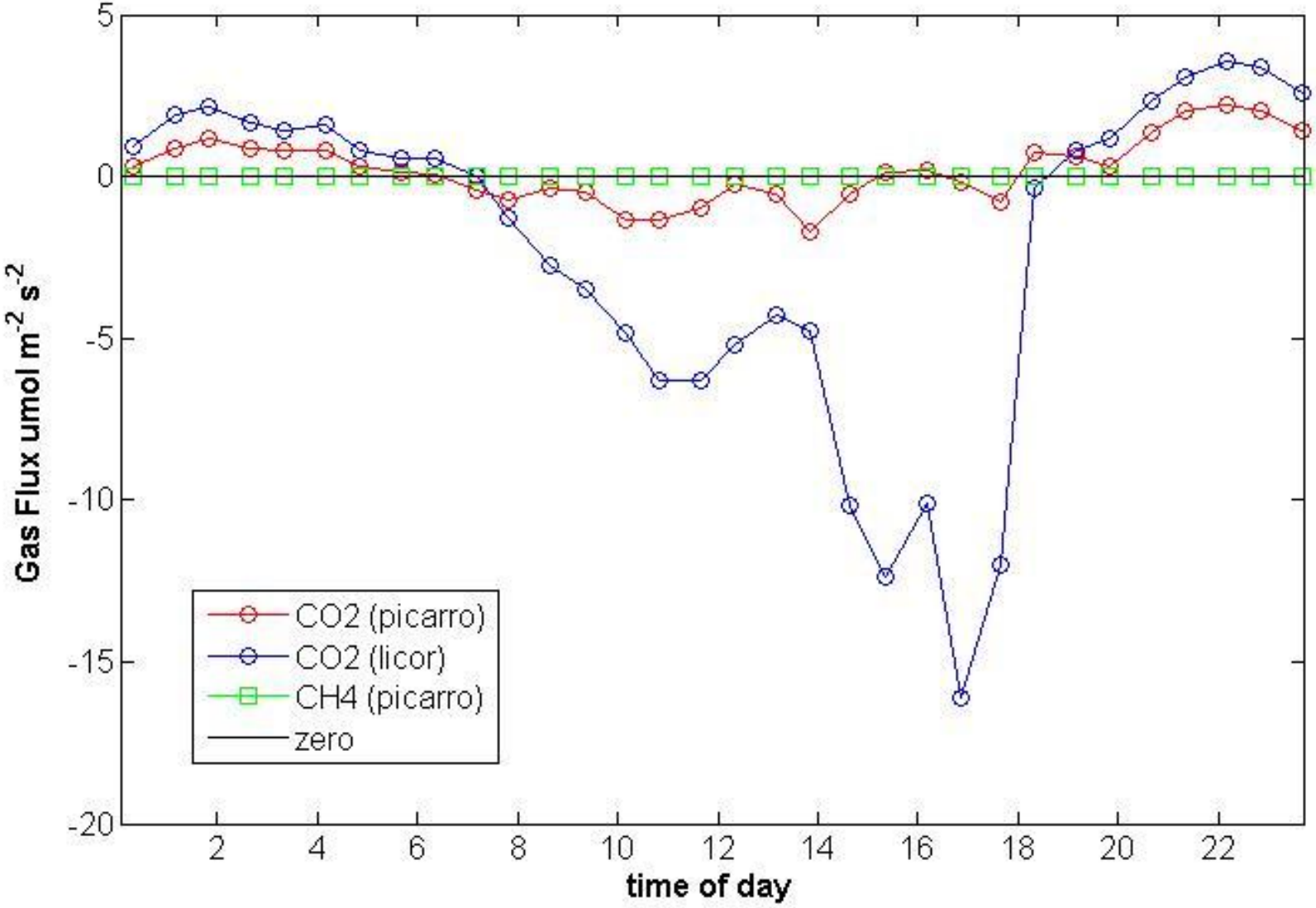
Conductivity

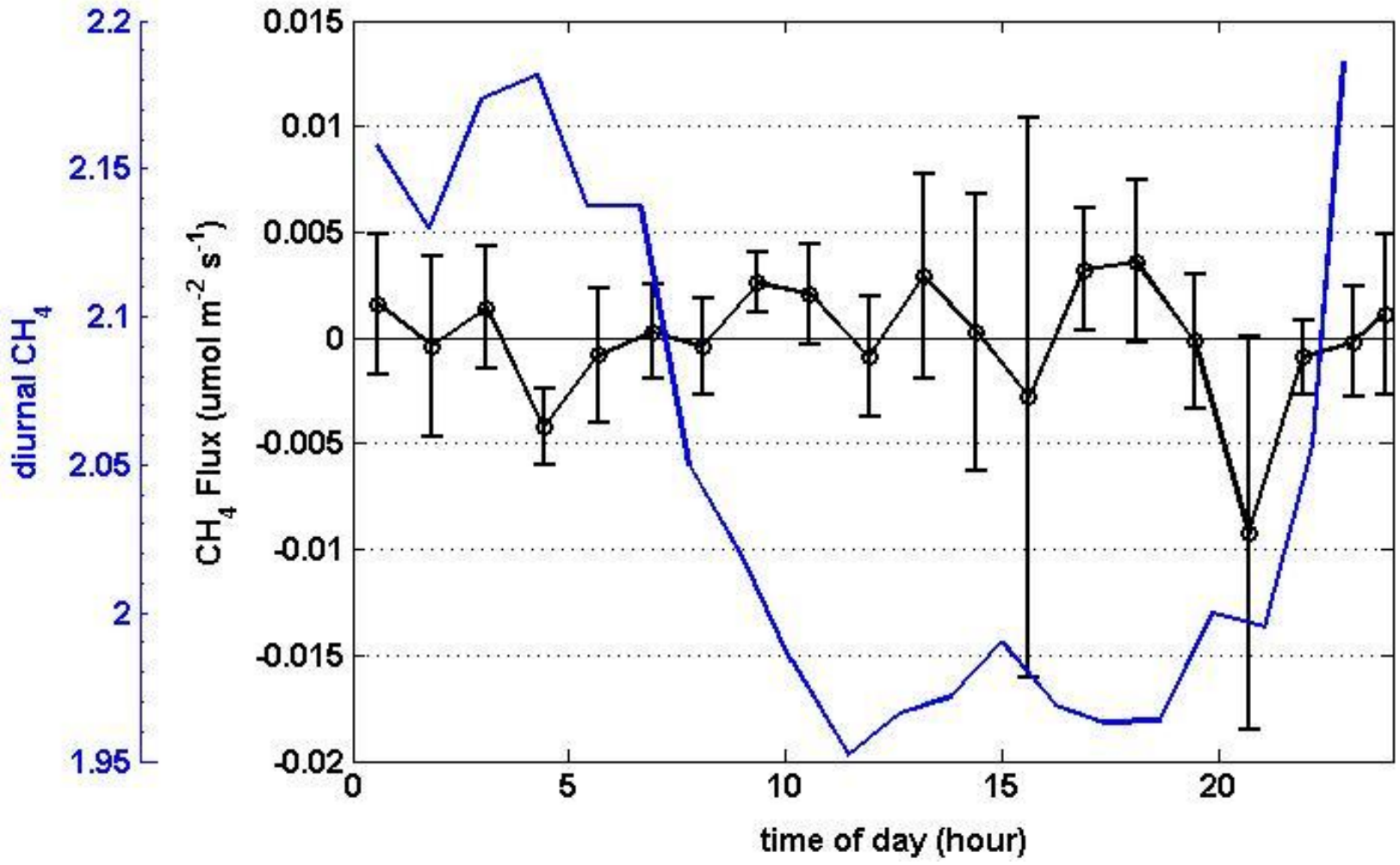
Picarro Superflux

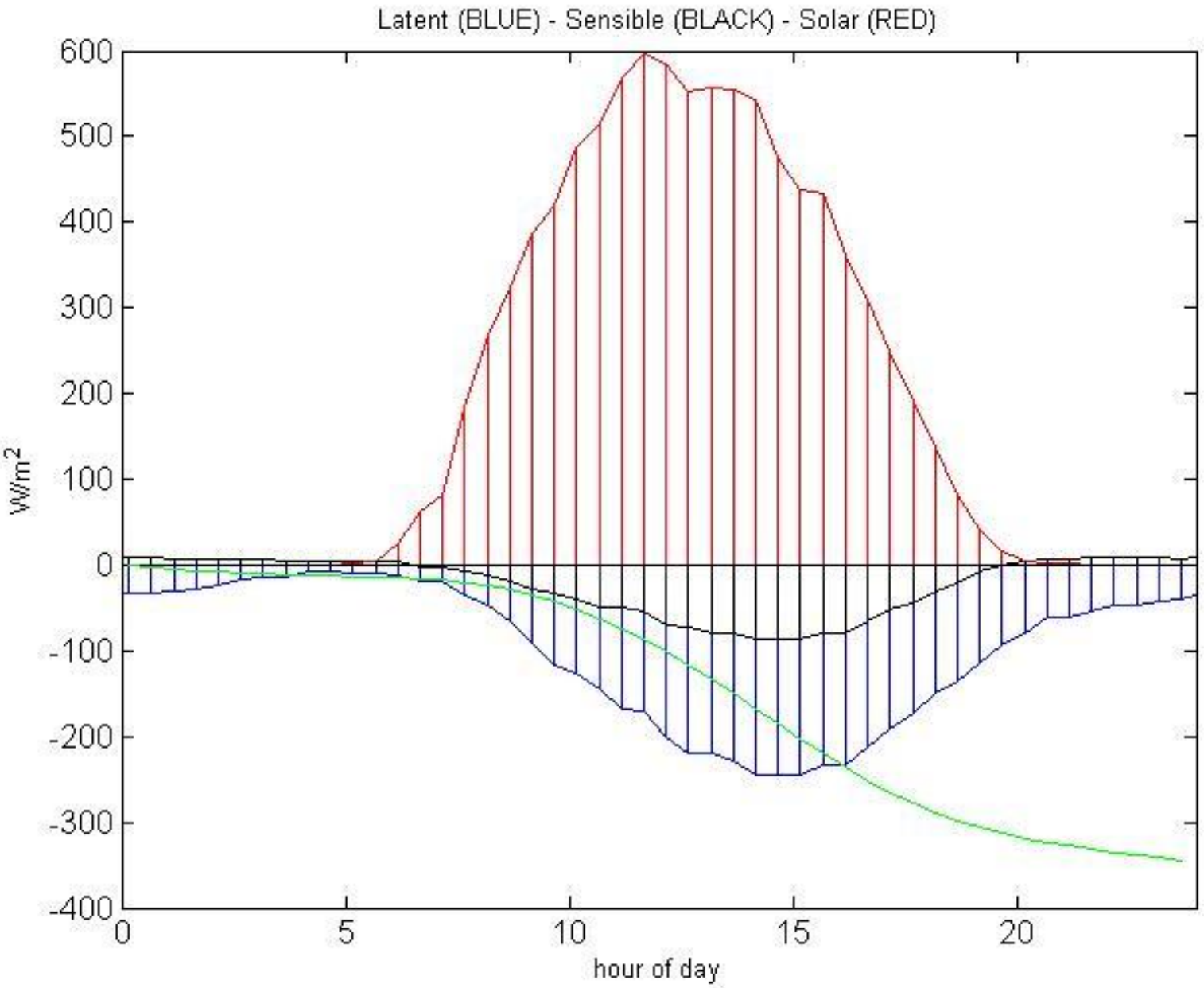



120
115
110
105
100
95
90
85
Air Temperature (F)
220.5
221
221.5
222
222.5
223
223.5
224
224.5
225
225.5
yearday 2011

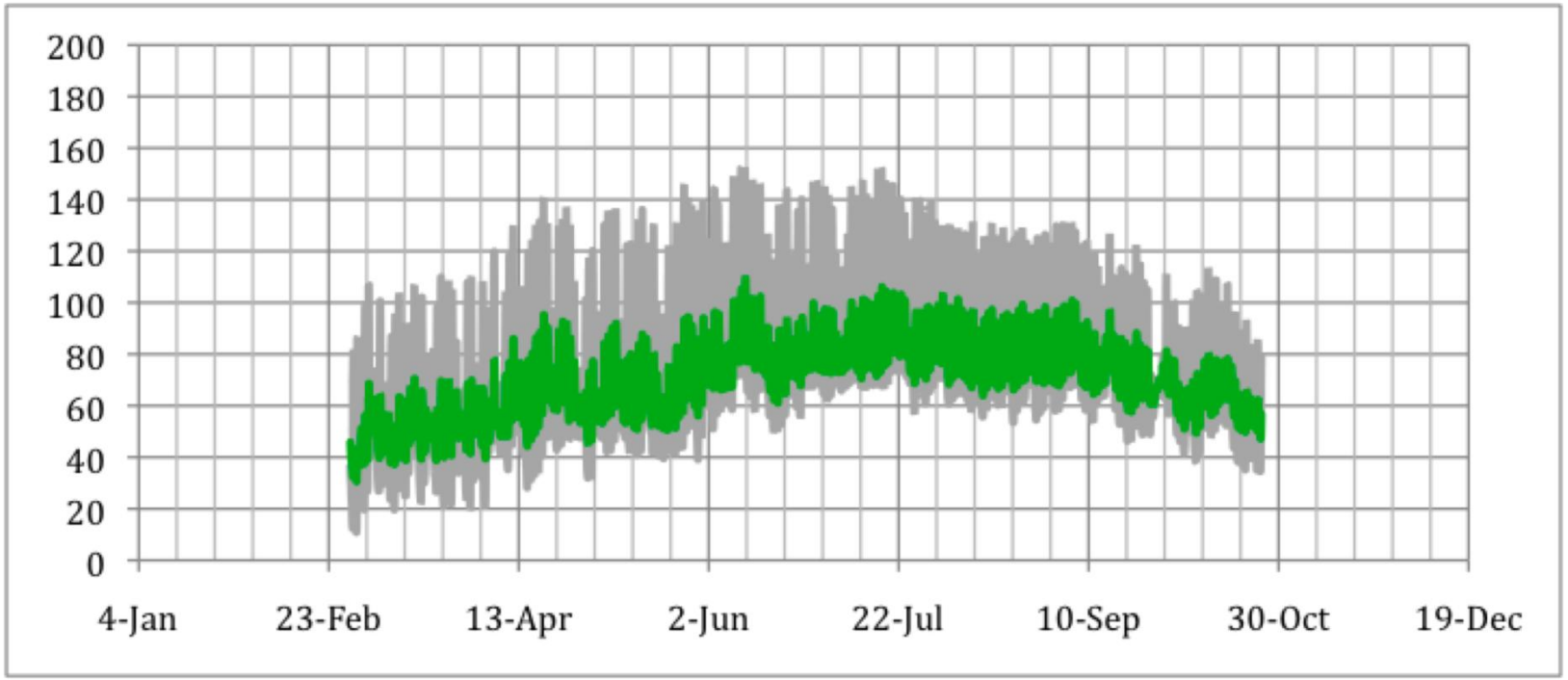

G2311-f
Atmospheric CH4 (umol/mol)
yearday 2011
3
2.8
2.6
2.4
2.2
2
1.8
220.5
221
221.5
222
222.5
223
223.5
224
224.5
225
225.5


5
0
-5
-10
-15
-20
2
4
6
8
10
12
14
16
18
20
22
Gas Flux umol m-2 s-2
time of day
CO2 (picarro)
CO2 (licor)
CH4 (picarro)
zero

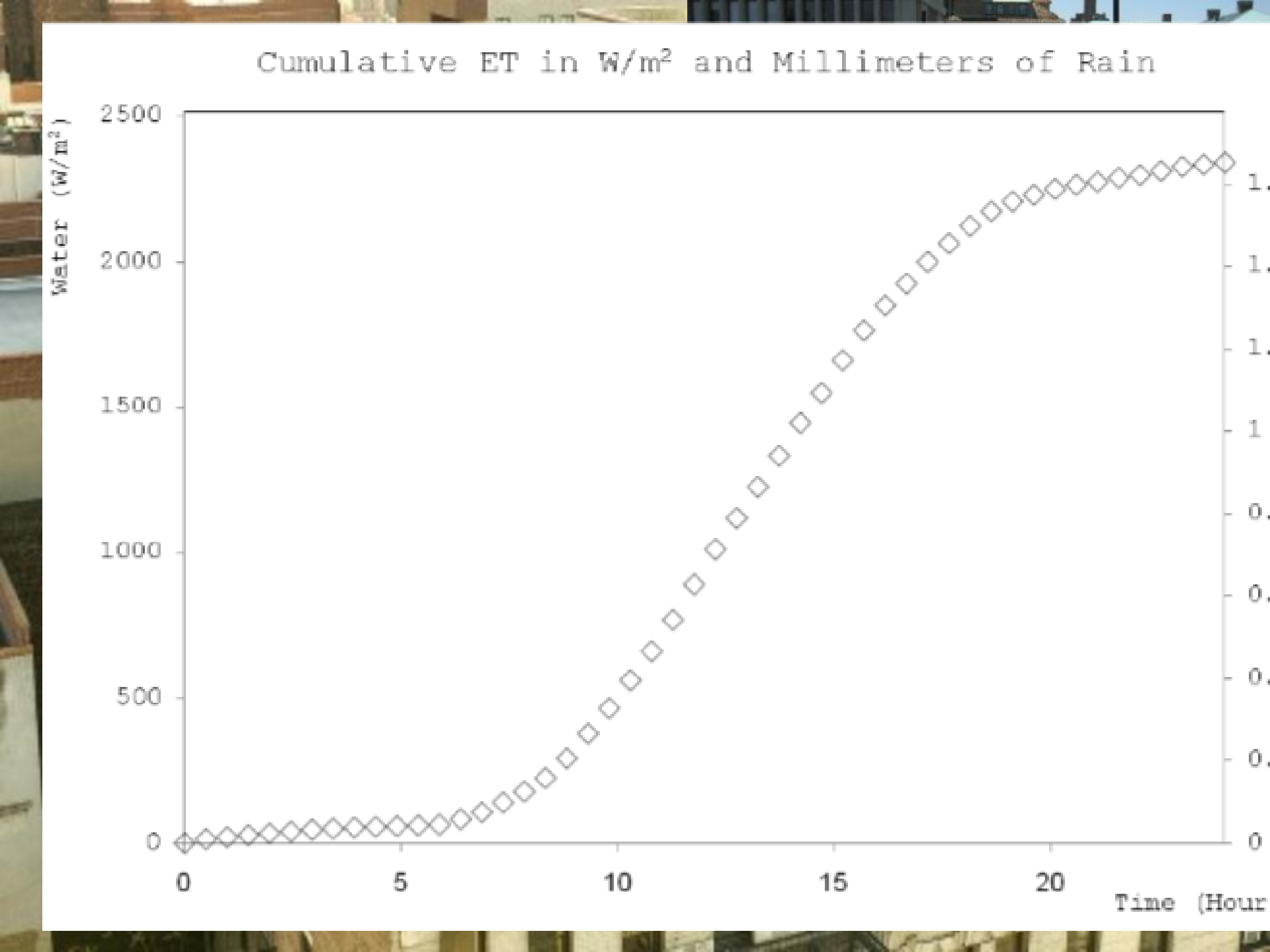

2.2
2.15
2.1
2.05
2
1.95
diurnal CH4
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
CH4 Flux (umol m-2 s-1)
0
5
10
15
20
time of day (hour)

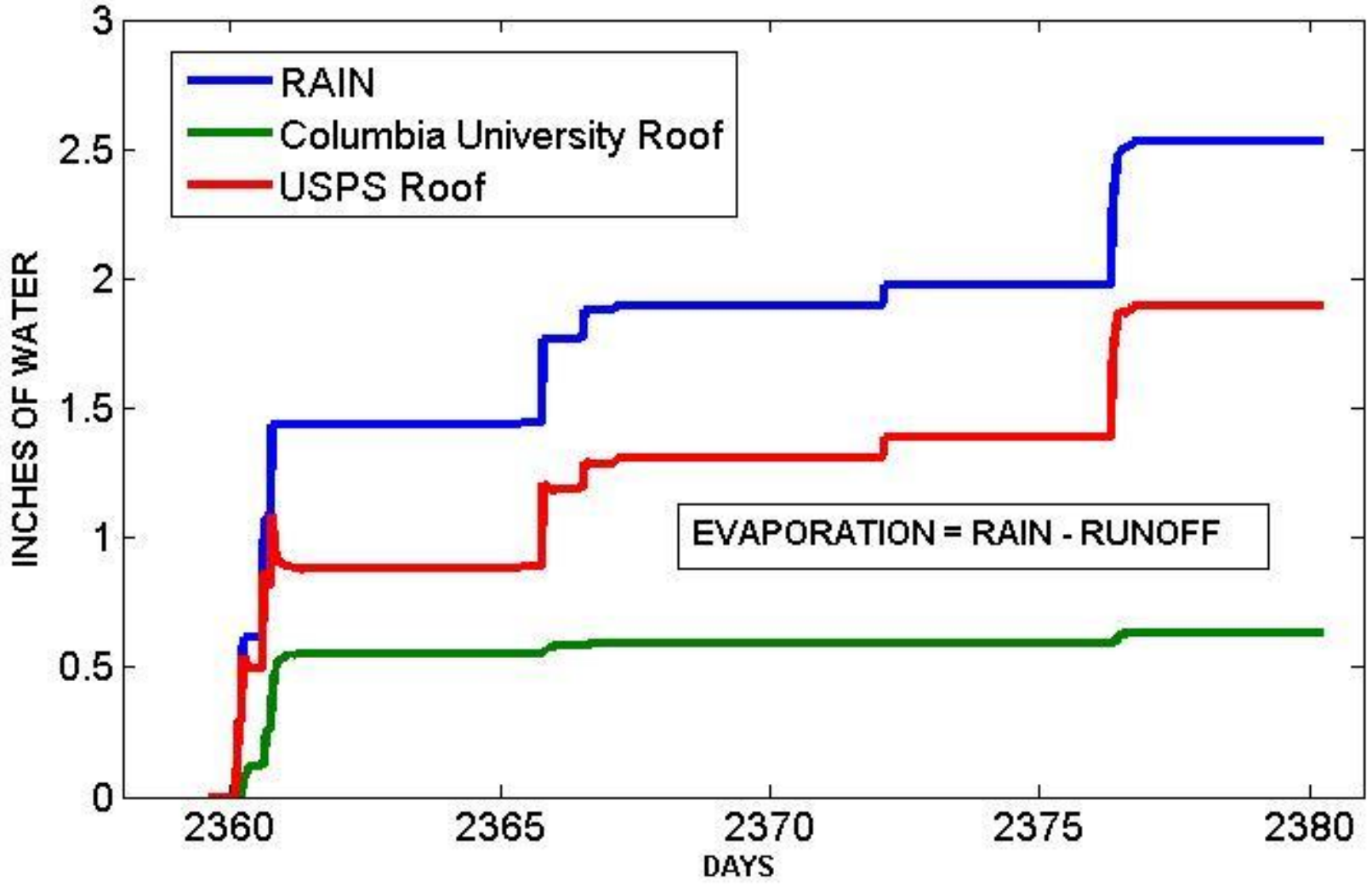

Latent (BLUE) - Sensible (BLACK) - Solar (RED)
600
500
400
300
200
100
0
-100
-200
-300
-400
W/m2
0
5
10
15
20
hour of day

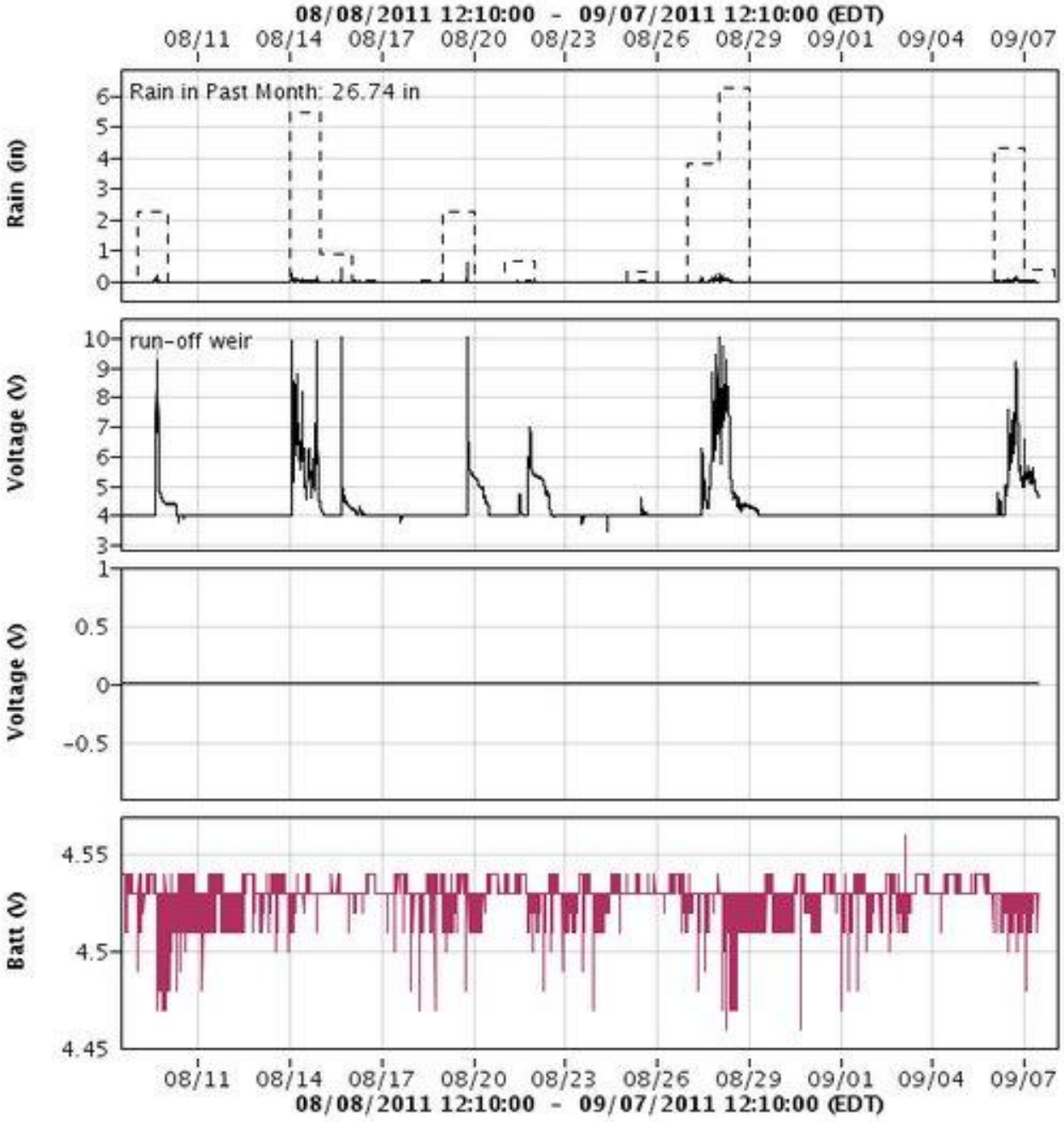
Heat Island Effect



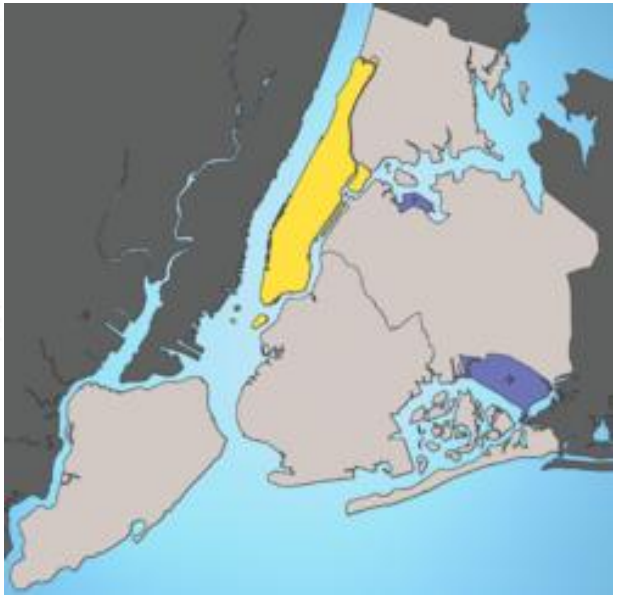
- **Comparison of green roof temperature (green line) with paver temperature (silver line = control roof).**


Cumulative ET in W/m² and Millimeters of Rain
Water (W/m²)
2500
2000
1500
1000
500
0
0
5
10
15
20
Time (Hour


RAIN
Columbia University Roof
USPS Roof
EVAPORATION = RAIN - RUNOFF
INCHES OF WATER
DAYS
0
0.5
1
1.5
2
2.5
3
2360
2365
2370
2375
2380



Measurement Panel of Rain and Runoff:
Aug 8 to Sept 8 2011
26.74” of RAIN



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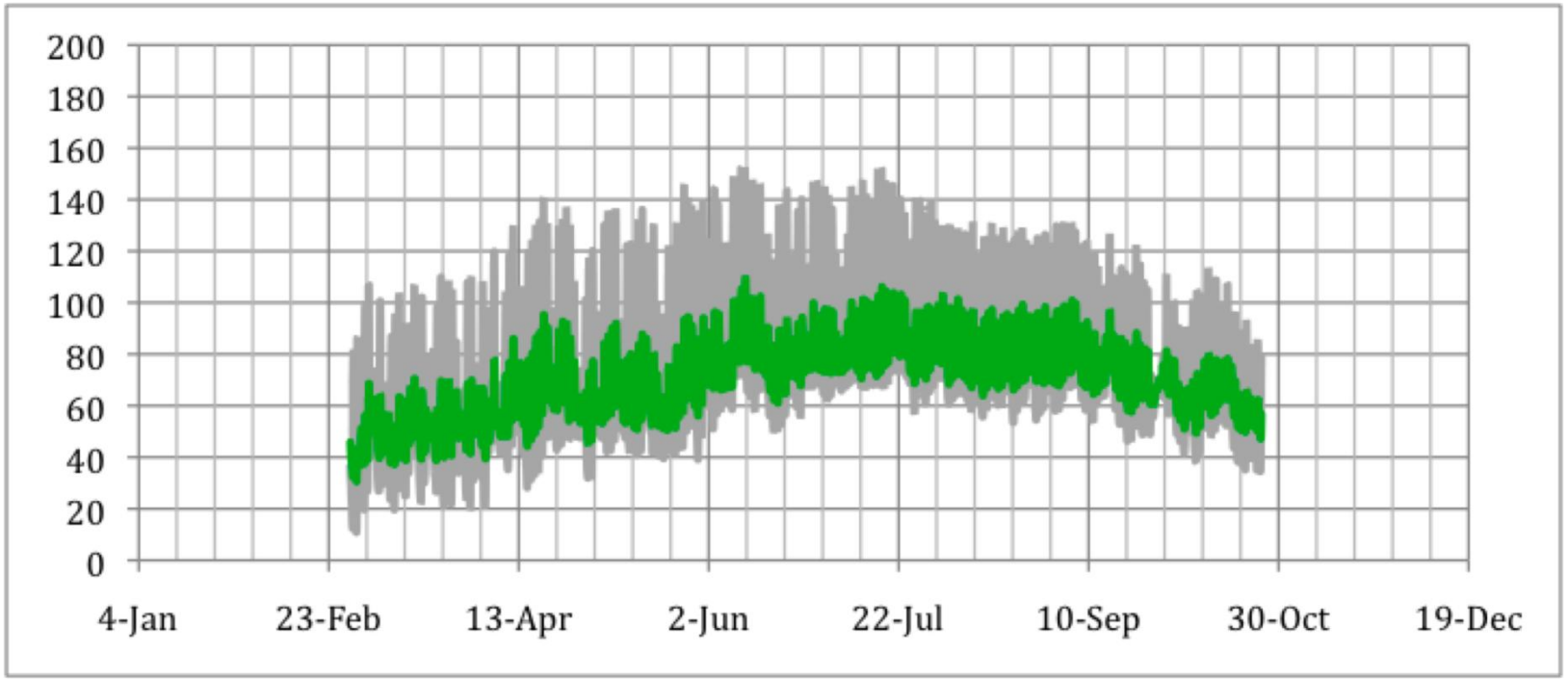
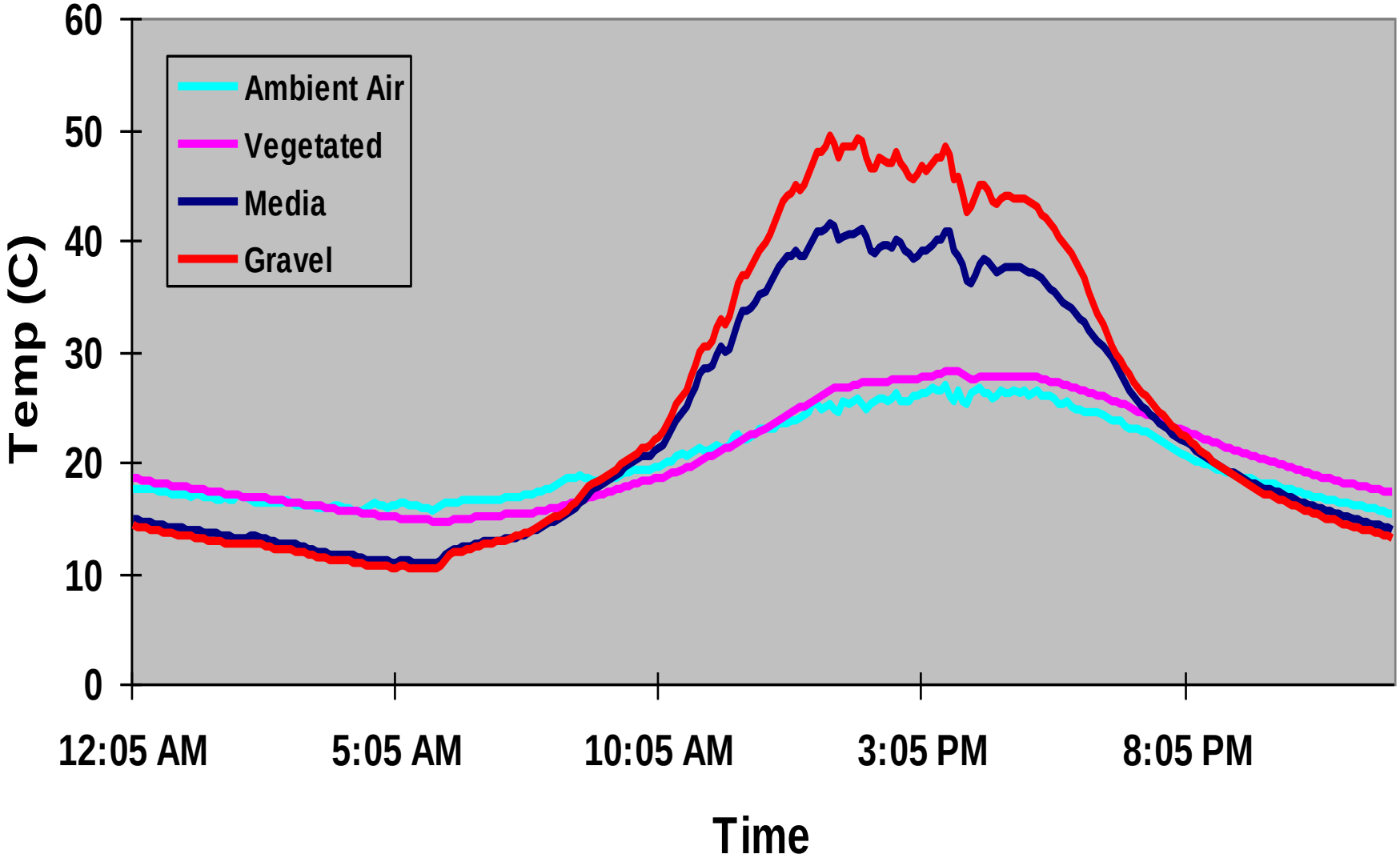
Heat Island Effect



- **Comparison of green roof temperature (green line) with paver temperature (silver line = control roof).**

Diurnal Substrate Temperature Trace

29 August (Peak load)



We use the integrated energy balance equation to solve for latent heat flux:

$$\int (SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow) = \int SH + \int LH + \int \text{Heat Cond Below}$$

$$+ \int \text{Internal Green Roof Energy Change Rate}$$

small over time

$$\int (SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow) \approx \int SH + \int LH + \int \text{Heat Cond Below}$$

$$\int (SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow) \approx \int SH + \int LH + \int \text{Heat Cond Below}$$