FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Measured Differences of Ground and Space Temperatures for Side-by-side Slab on Grade Residences with and without Carpet

Buildings XIII

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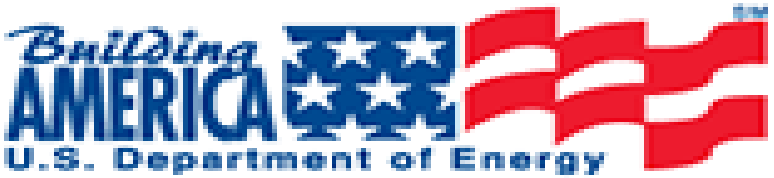
FSEC®

A Research Institute of the University of Central Florida

Thanks to

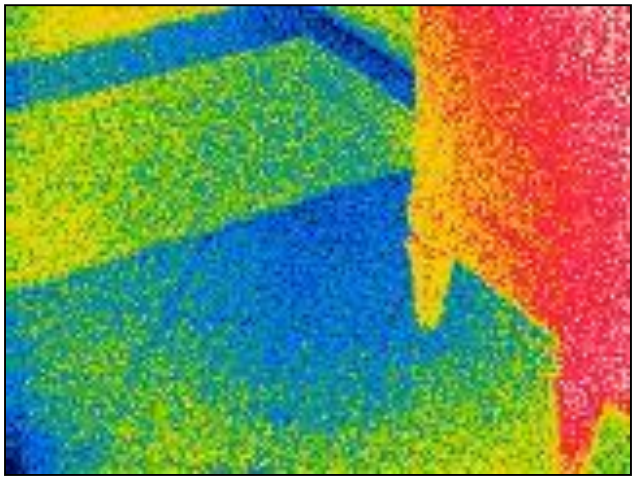
- Florida Energy Systems Consortium for initial funding of labs

- DOE Building America program for funding of experiment



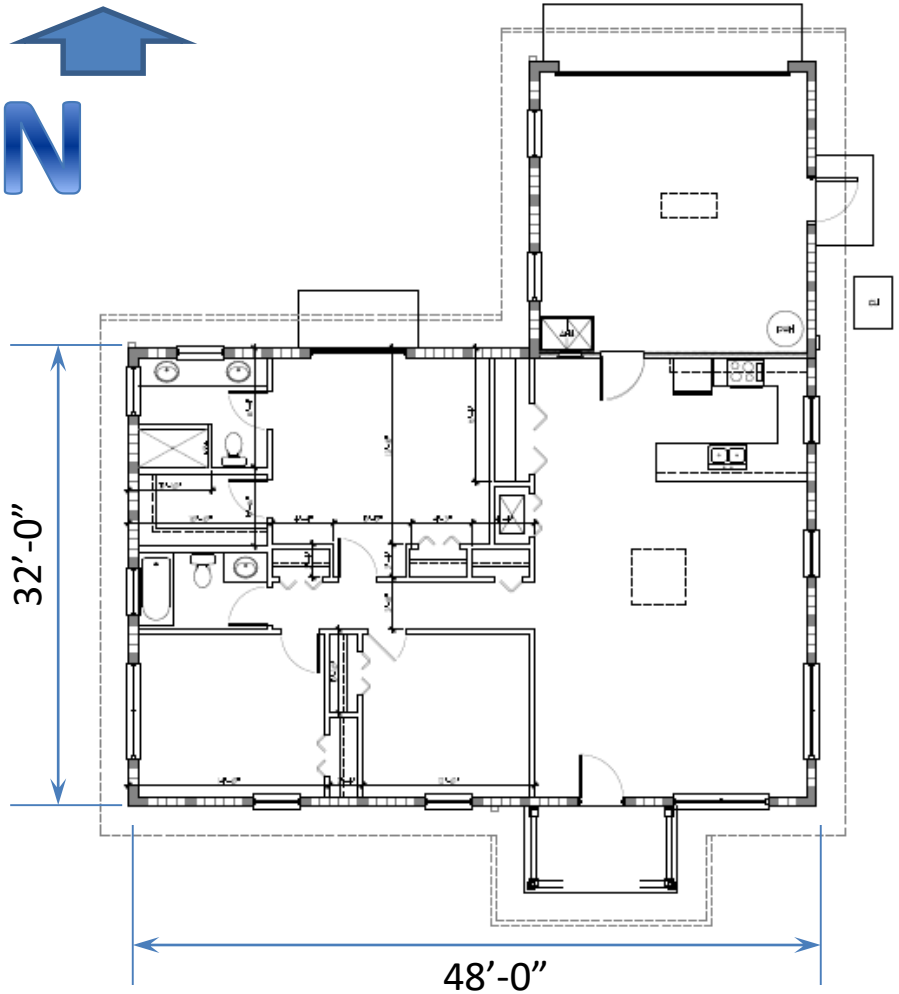
Can the Ground Slab Provide Free Cooling in a Hot Climate?

- Evidence like this from previous thermography….
- Advantages for slabs for cooling?
- What are edge gains like?
- Center heat sink in summer?
- Edge losses in winter?
- What kind of advantages?



- Two identical side-by-side 1536 ft^2, concrete block, slab-on-grade residences
- Single pane fenestration, evenly distributed
- No concrete block wall insulation
- R-19 ceiling insulation
- SEER-13 w/strip heat HVAC systems

Lab Home Floor Plan



Interior walls not present in current test configuration

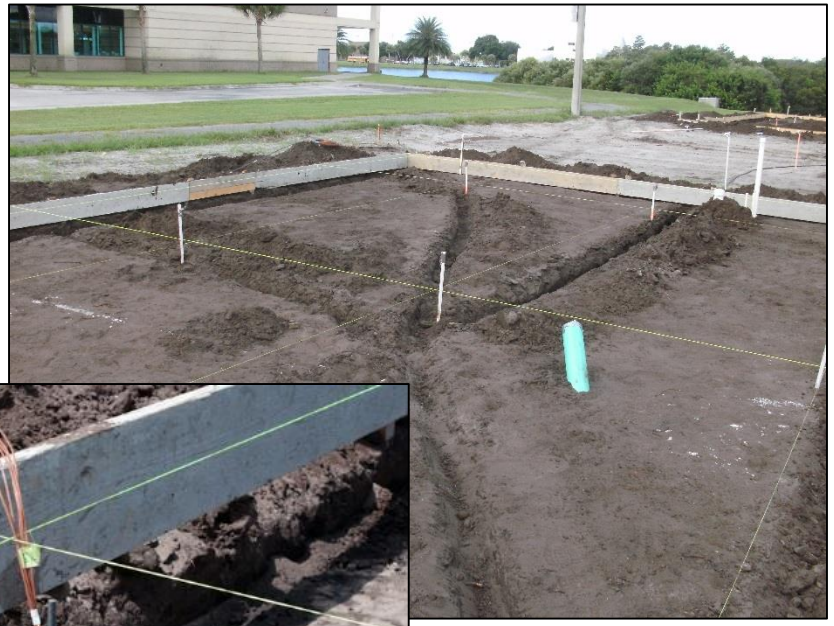
Occupancy Gains

- Automated (computer controlled) heat and moisture gains scheduled by time of day
- Based on RESNET lighting, appliance and miscellaneous energy usage amendment
- Imposed using NREL/Building America benchmark hourly schedules with slight modifications
- Includes lighting and appliance gains and occupant gains
  - Sensible gains ≈ 15.5 kWh/day
  - Latent gains ≈ 12.1 lb H_2O/day

Ground Sensors

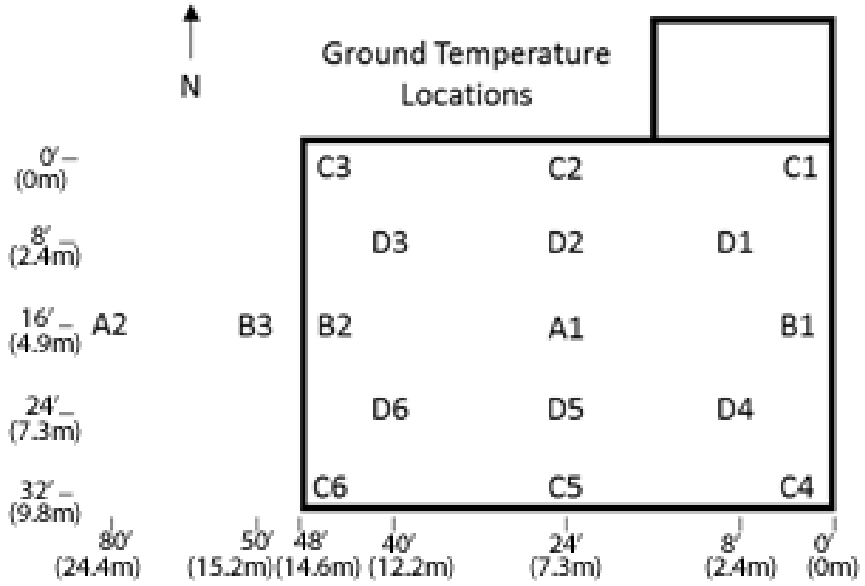
- Homes Built in 2010
- 156 sensors installed

Pre-Slab Installation



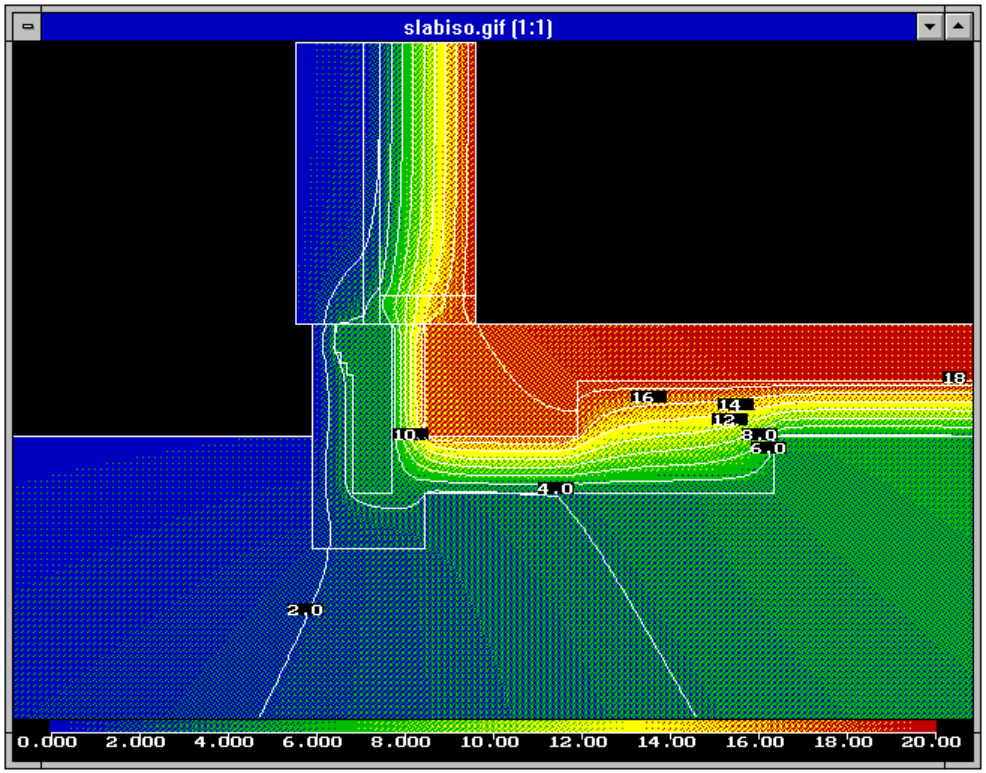
Slab Sensor Locations

Key	Quantity	0’	1’	2’	5’	10’	20’
A	3	✓	✓	✓	✓	✓	✓
B	6	✓	✓	✓	✓	✓	✓
C	12	✓	✓	✓	✓	✓	
D	12	✓	✓	✓			



Empirical data vs. Simulation

- Most existing conclusions are from simulation
- Assumes constant interior temperature
- Whereas actual varies
- Water table…
- Rain…
- Uncertainties
  - Conductivity
  - Film coefficients
  - Solar effects on edges



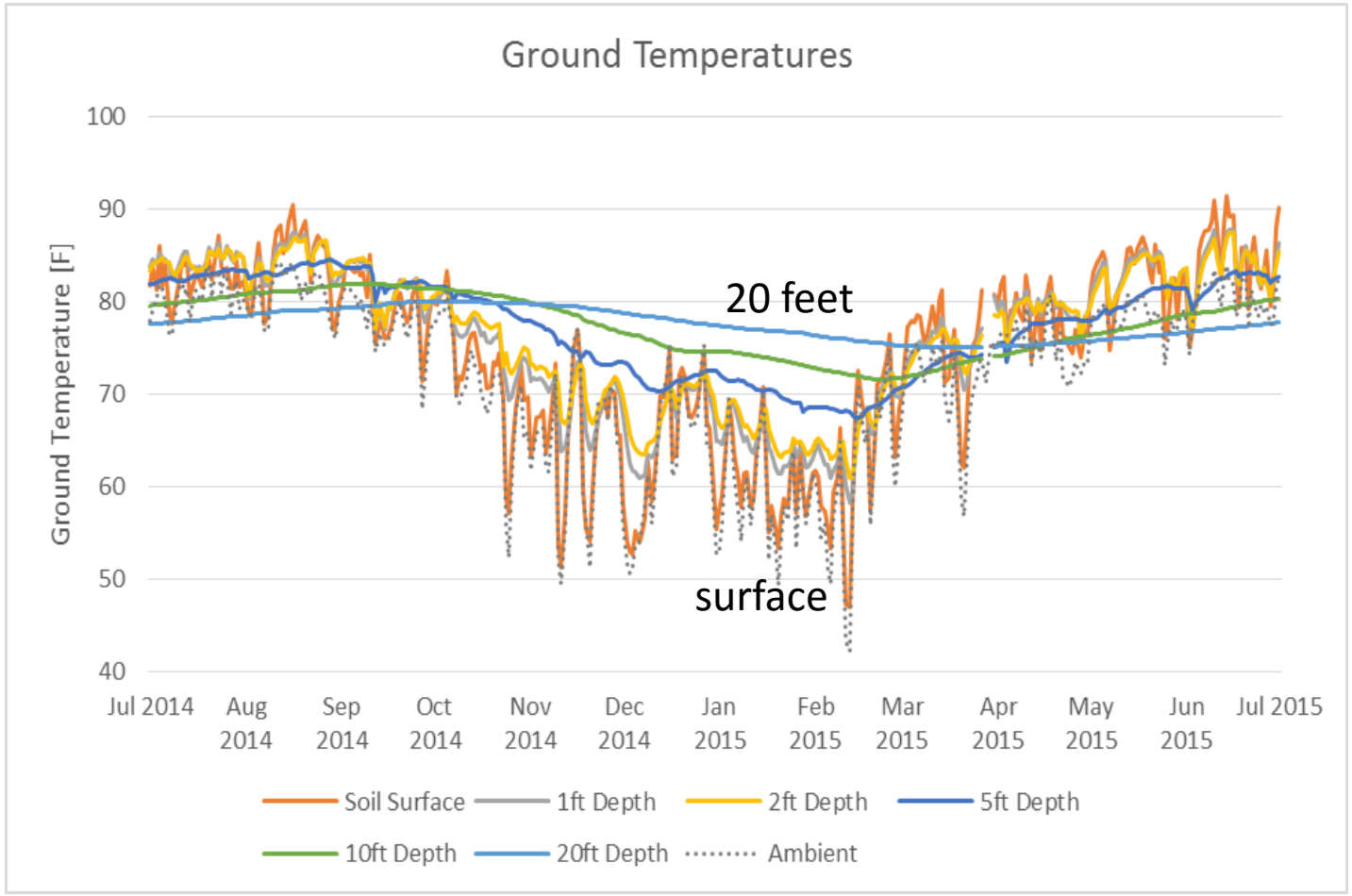
Experiment

- Houses Built in 2010
- Uncovered slab from 2010 – late 2013
- Carpet put in East Lab
- Wall sections added to both labs for mass

Limit of Experiment

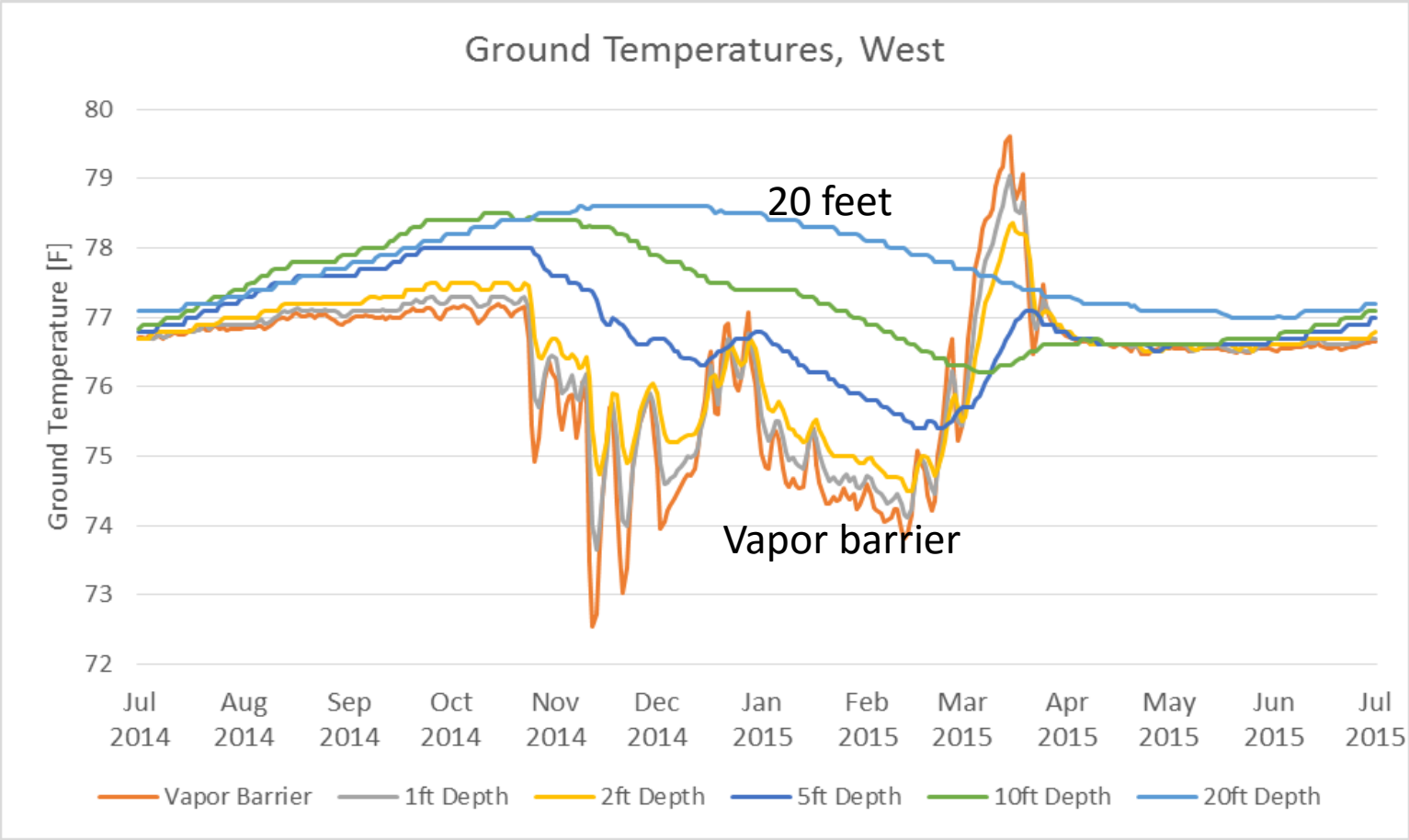
- Unoccupied labs provide consistent internal loads
- Does not account for any direct contact benefit/detriment (bare feet on cold slab vs. carpet)

Measured Ground Temperature

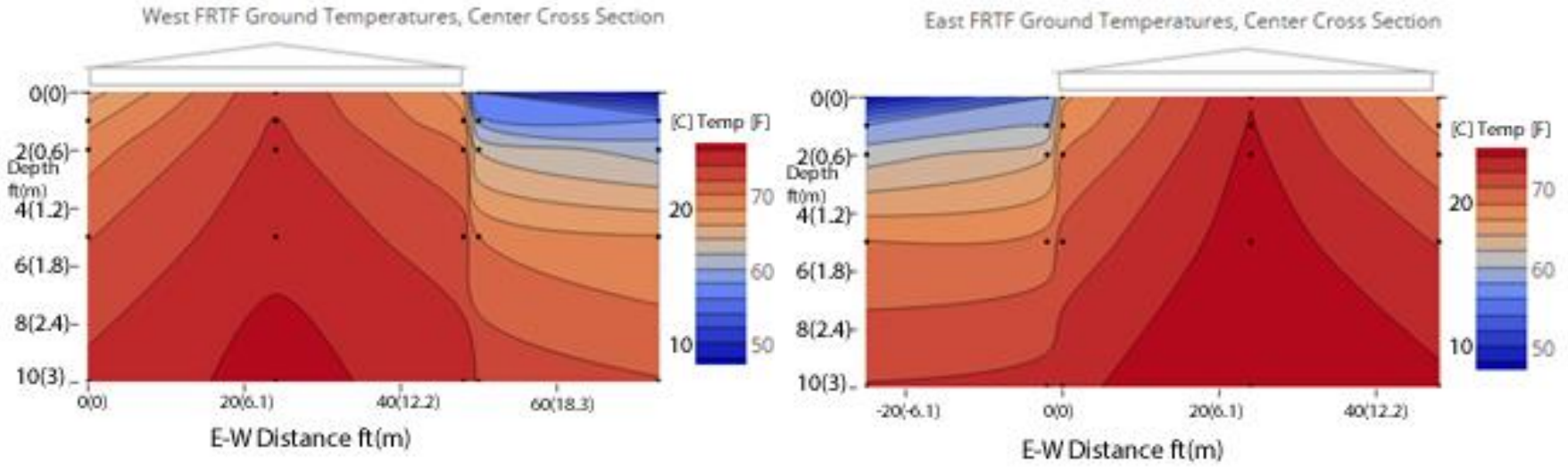


Measured at point 32.5’ from each building

Temperature Under Center of Slab Building



Winter Isotherm Plots
Feb. 20, 2015



West uncovered slab loses heat (warms ground) slightly more than the East carpeted slab.

Winter Differences

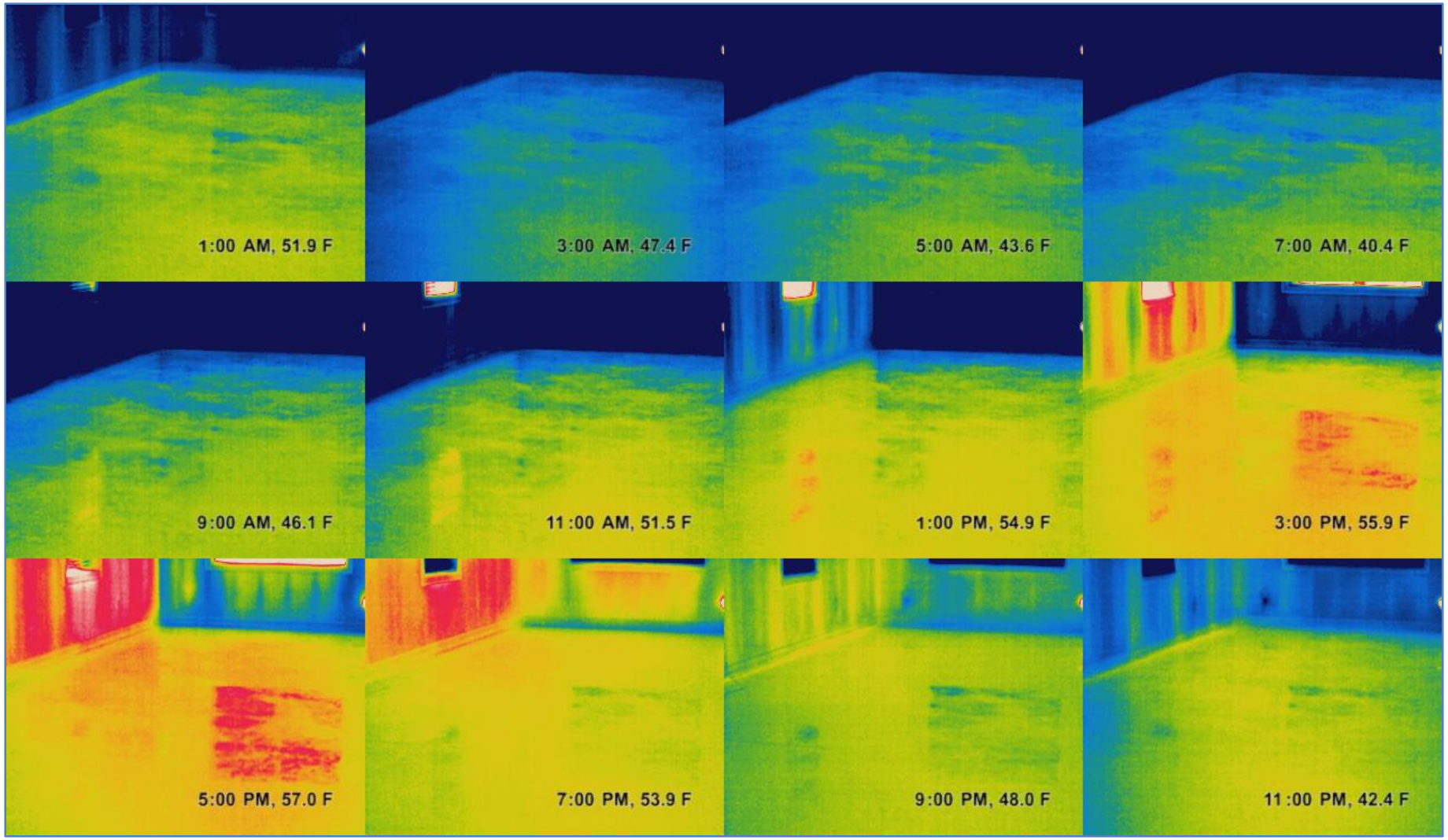
4 days of Temperature less than 50 F (10 C)	East (Carpeted)	West (Exposed Slab)	Difference	% Difference	Standard Deviation	Standard Error	t-stat (df=95)	p-value
Interior Temp [°F]	75.43	74.91	0.52		1.27	0.13	4.00	<0.001
Interior RH [%]	30.16	30.31	-0.15		7.64	0.78	-0.20	0.844
Interior DP [°F]	41.45	41.13	0.33		2.55	0.26	1.27	0.208
Energy Use [kWh/day]	22.52	23.46	-0.93	-4.1%	3.06	0.31	-2.99	0.004

Labs maintained 73 F minimum temperature with no maximum during heating experiment

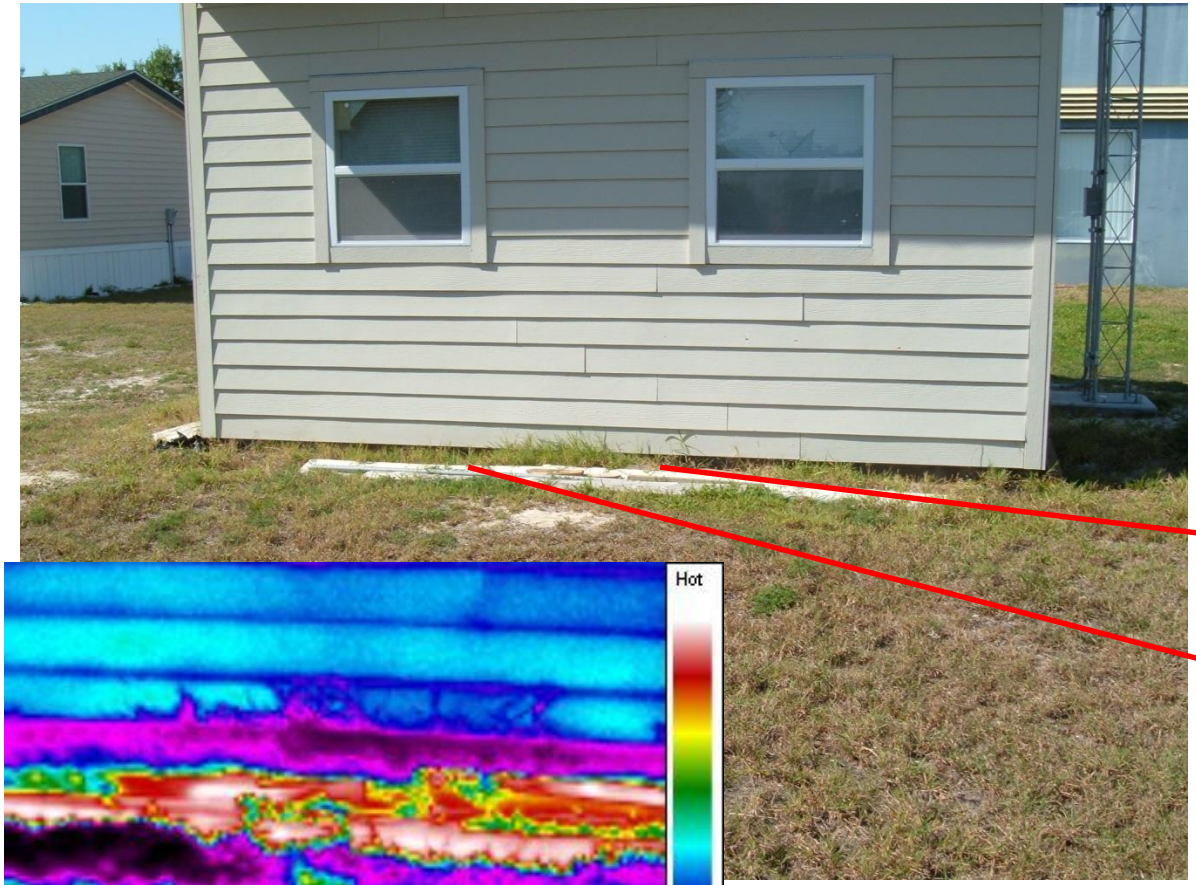
Time-lapse thermography

Time Lapse Thermography on Coldest Day in Central Florida 2013

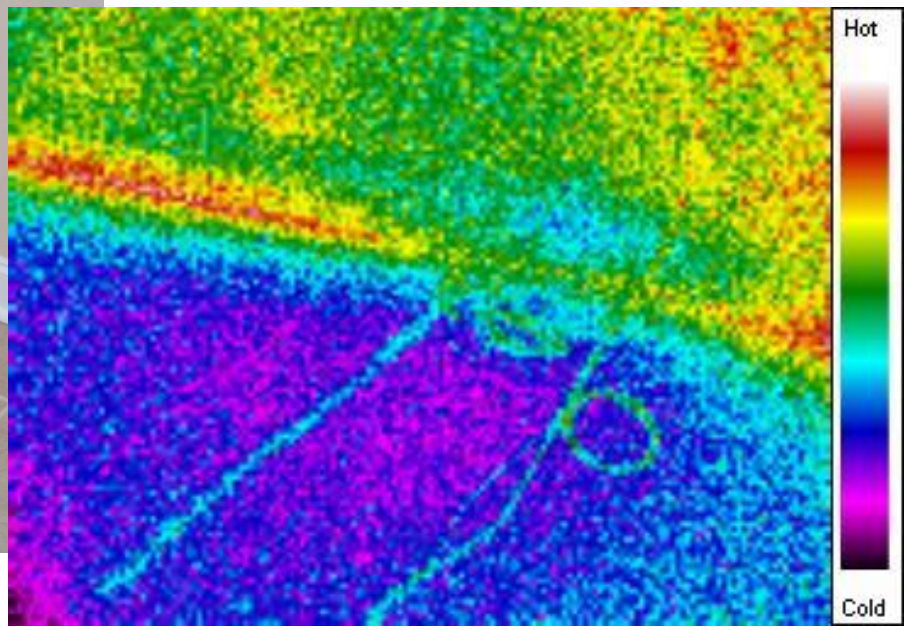
Time Lapse Cold Day 2013



Small Test Buildings: Interesting at the edges

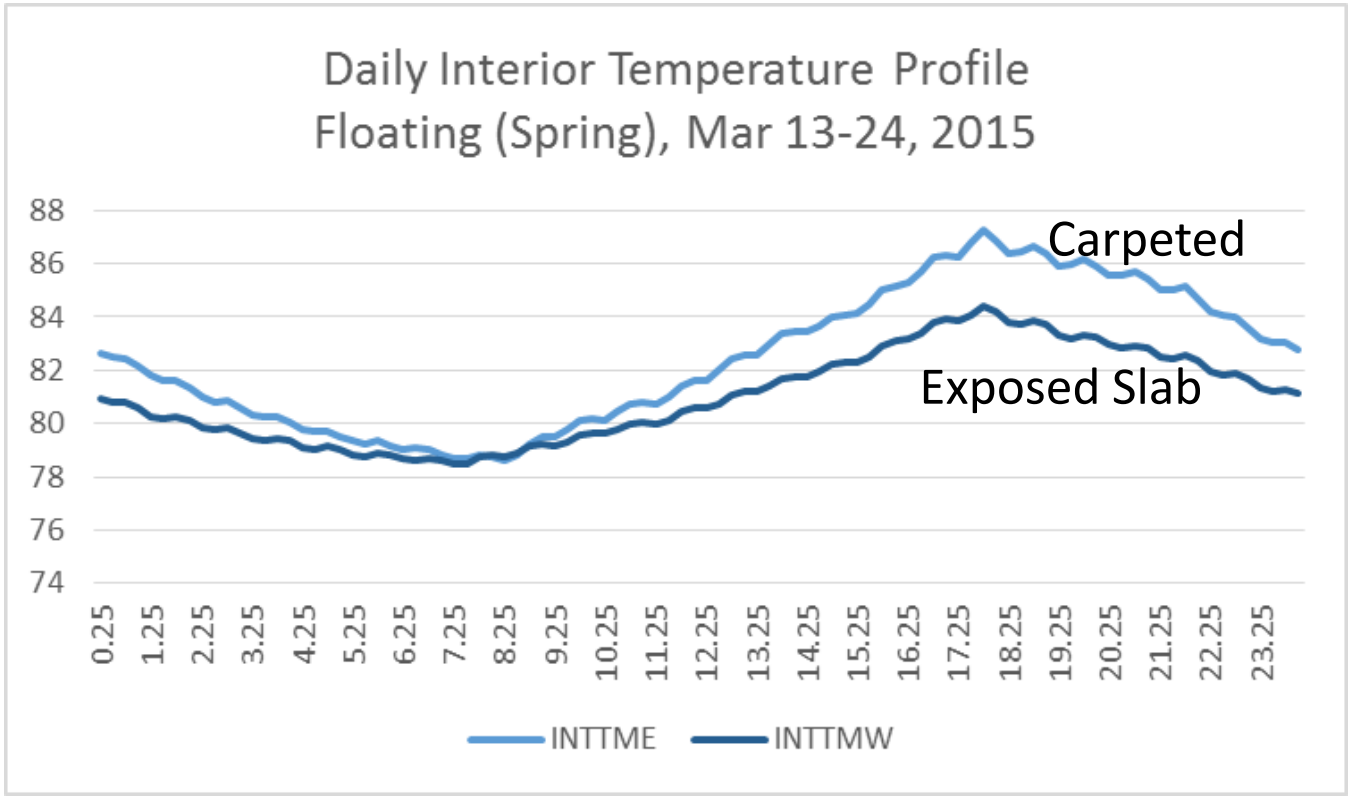


Visible impact on interior



Could perimeter plant shading impact foundation heat gain?

Spring Season (Floating Interior Temperature)



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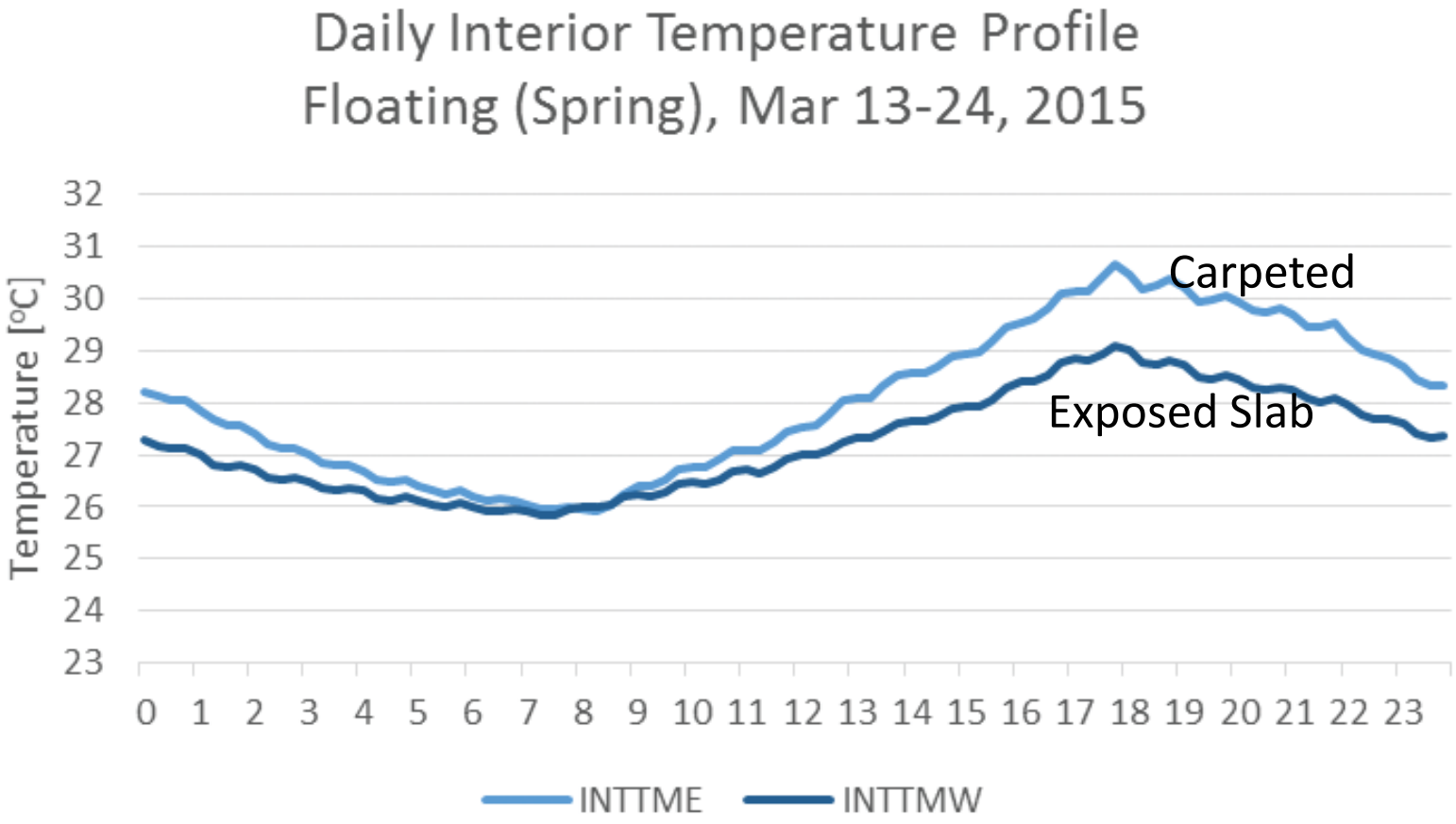
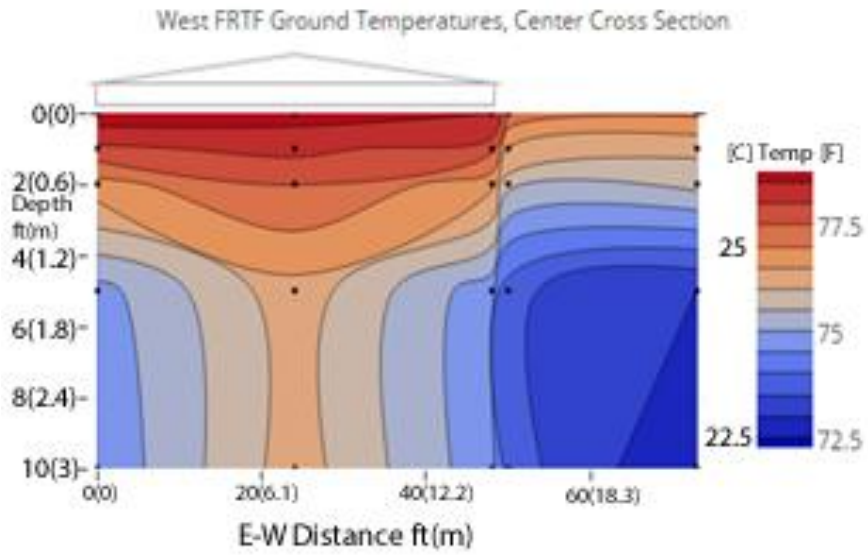
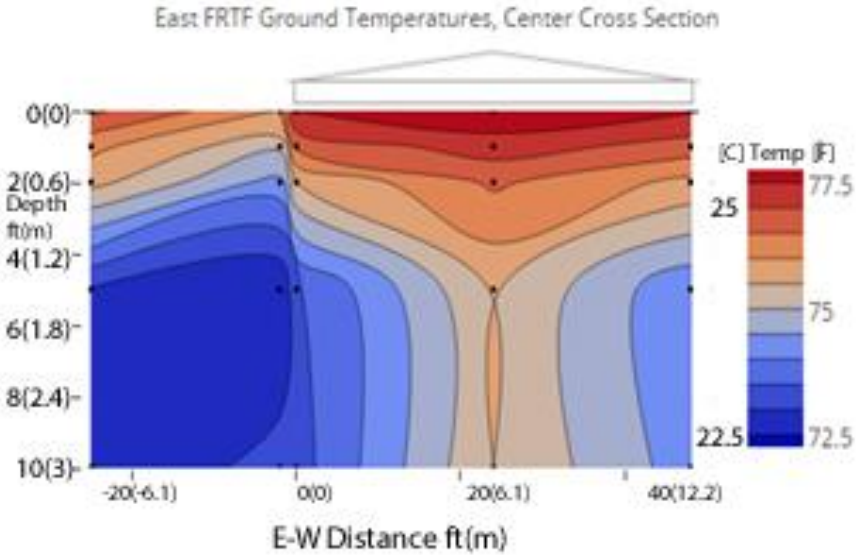


March Floating Period Contours

Exposed Slab



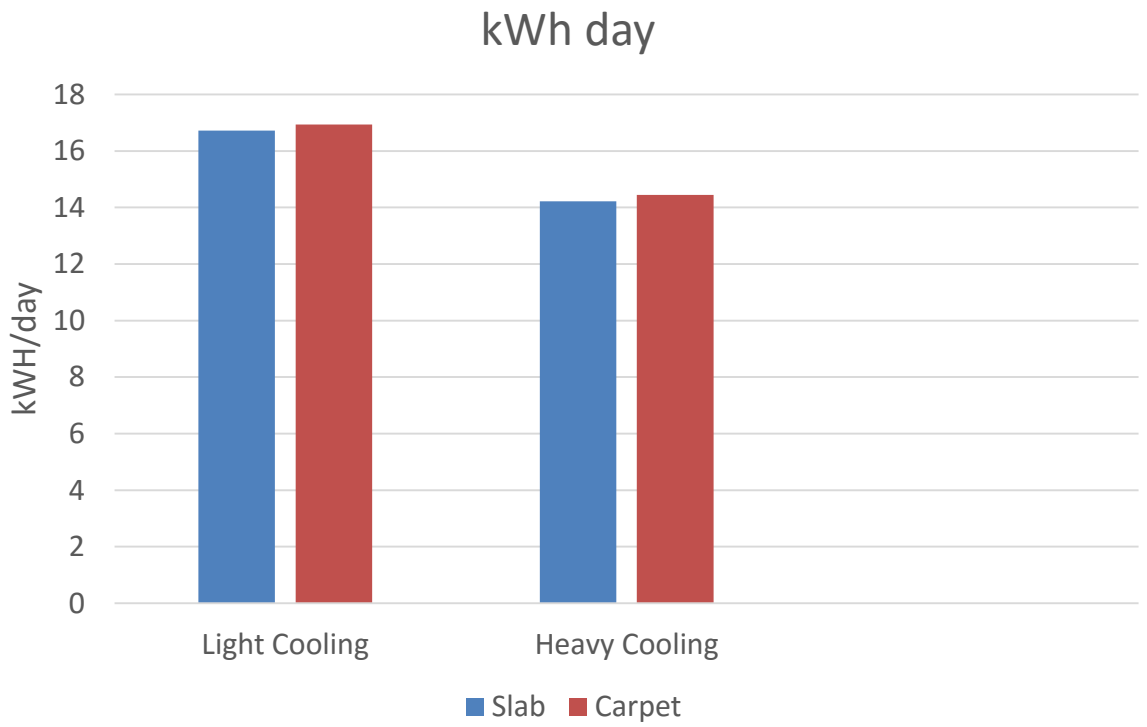
Carpeted



West uncovered slab loses heat (warms ground) more than the East carpeted slab.

Summer Period

- Summer analysis broken into light cooling (132 days) and heavy cooling (155 days)



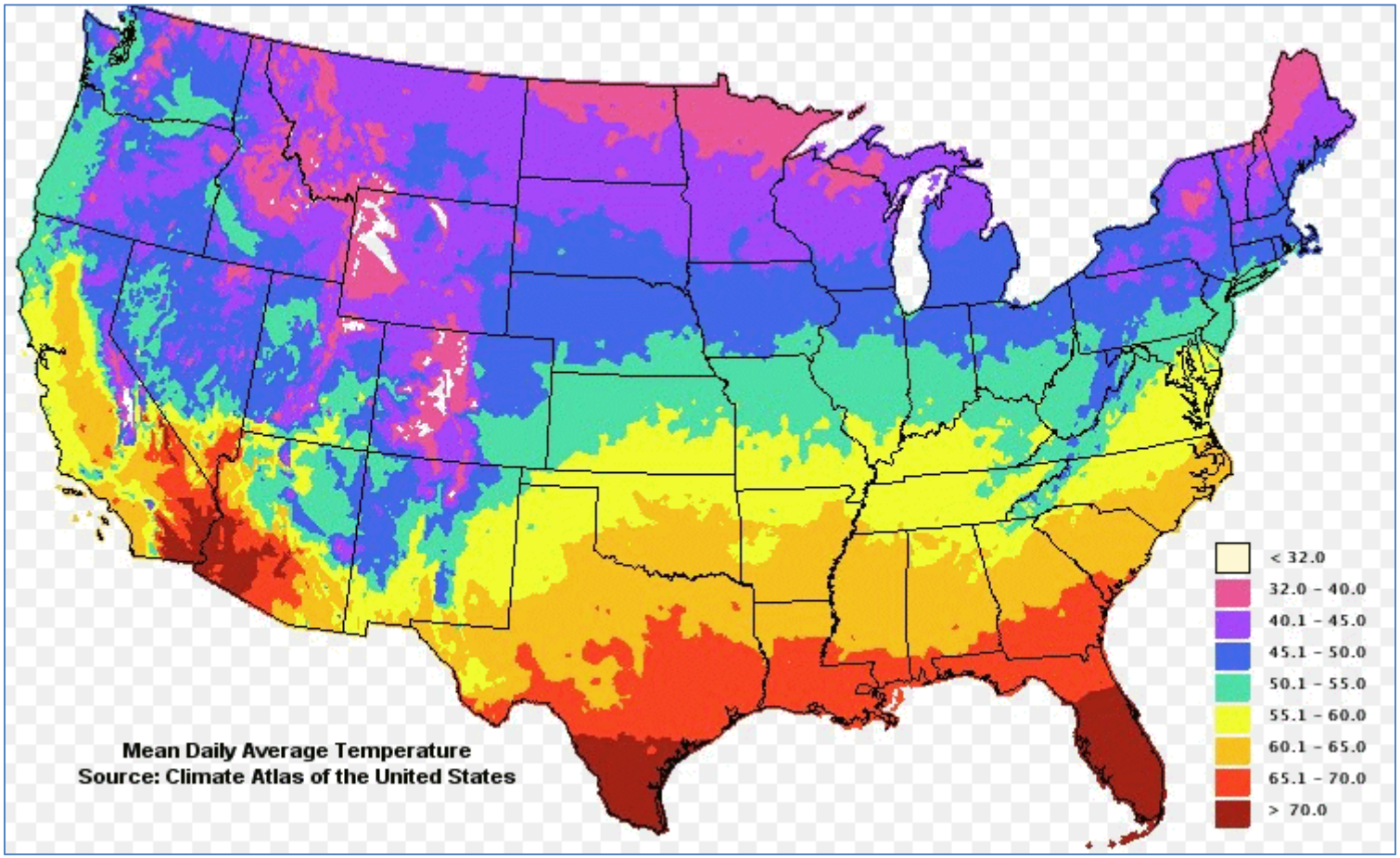
General Findings

- Little evidence slabs provide cooling advantage
  - At 77 F summer setpoint ~ adiabatic
  - Deep ground is 76.8 F at 20 ft depth
- Carpeted floor helps w/ heating in C. FL in winter despite earth temperature (4.3% reduction in heating energy use over season) – could be higher percentage in a high performance home

Limitations

- Central Florida deep ground temperature is near cooling set point temperature
- May prove cooling benefit for a ground temperature a few degrees lower
- Benefit will be subject to set points maintained.
- Summer edge effect may vary for raised fully sun-exposed slab edges. Shrubs would limit edge temperature rises. Ours was ground level with grass.

Average Annual Temperatures (NOAA)



Implications

- Most building models predict cooling use reduction for tile floors in Central Florida and do not show heating savings
- Need to revisit models and effect of edge versus earth below slab

Questions?

Thank You

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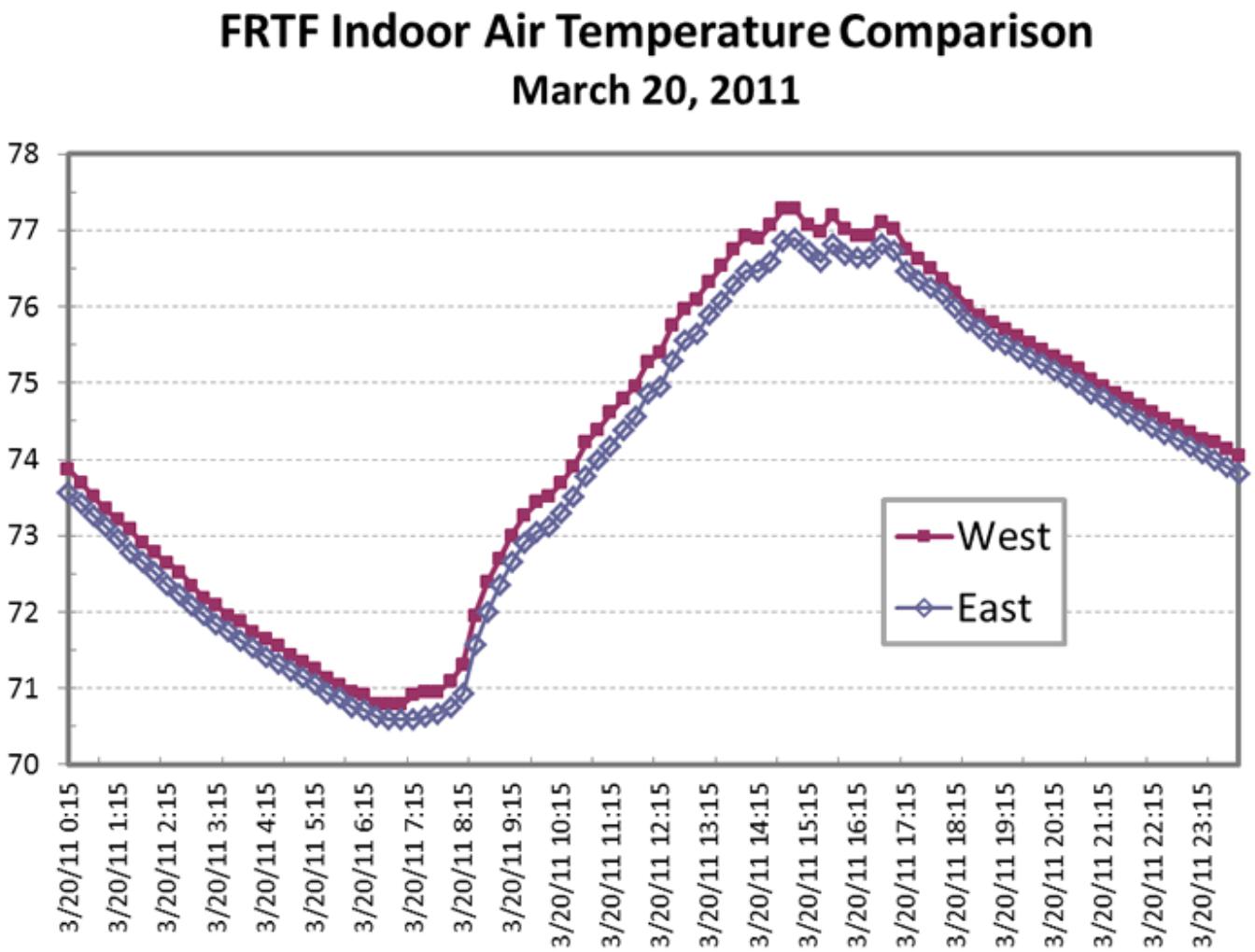
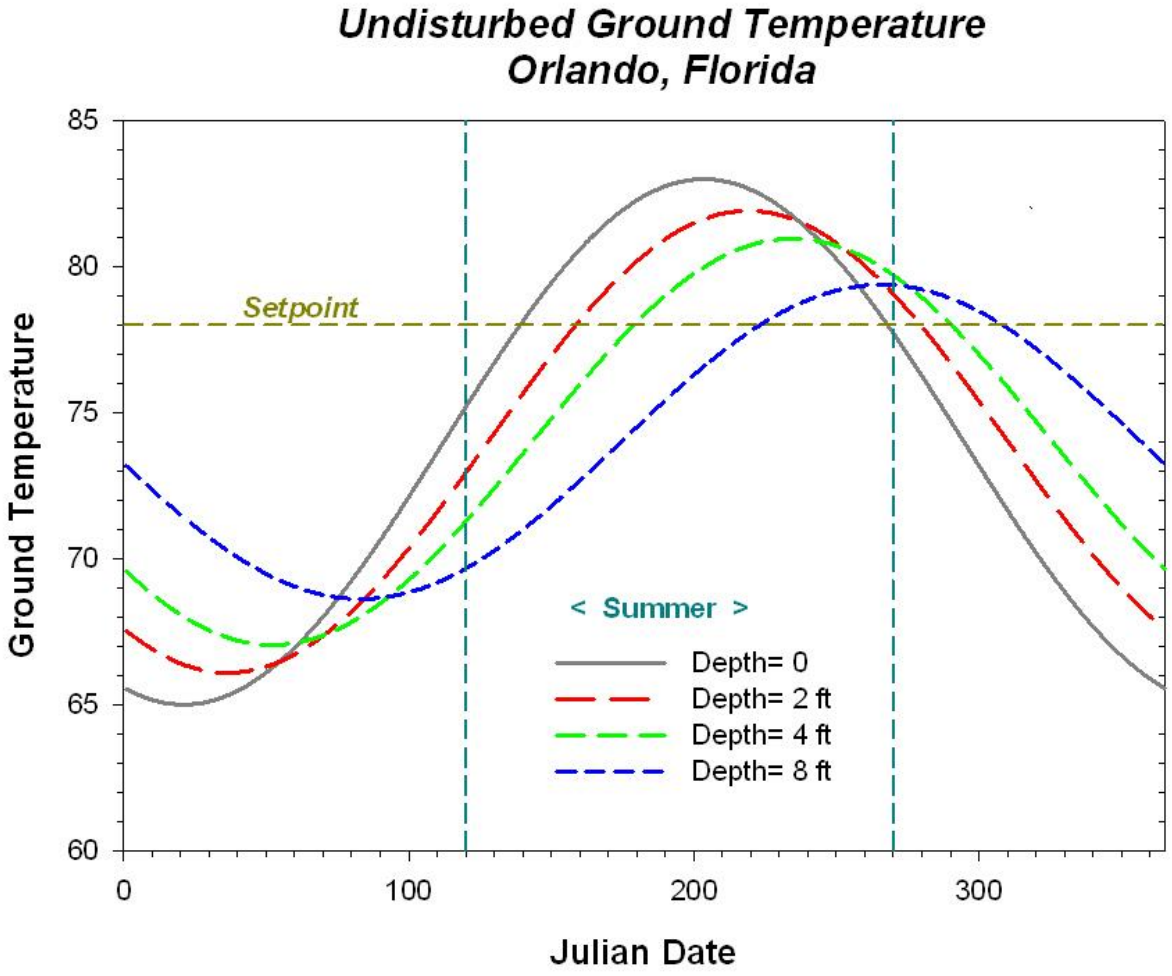
Extra Slides

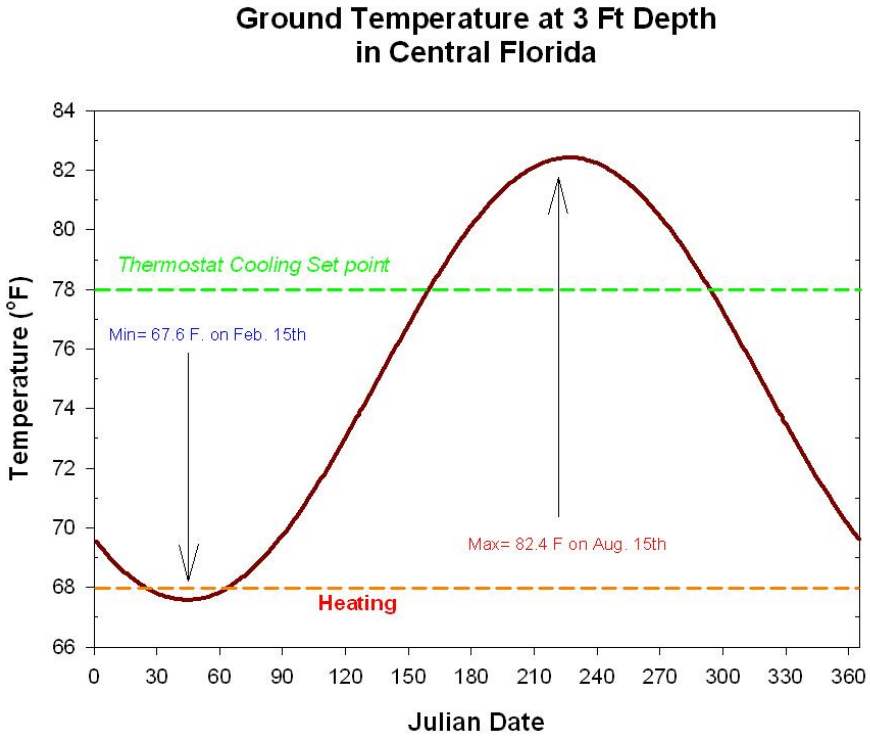
Null Tests – No HVAC

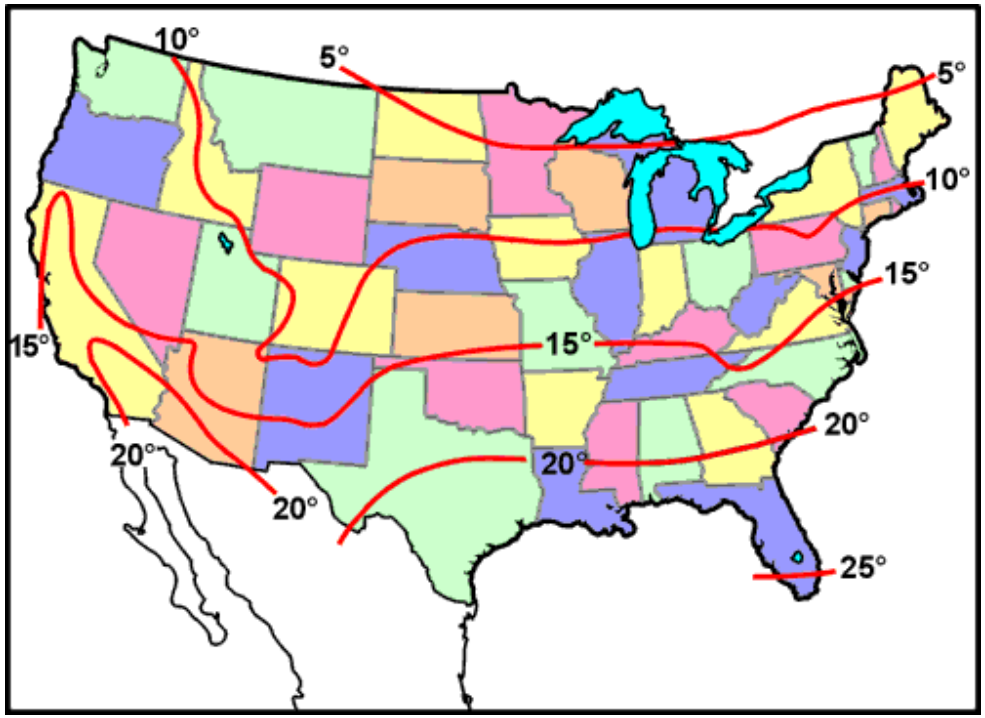


Estimated Undisturbed Ground Temperature in Orlando, FL



Results likely change with location

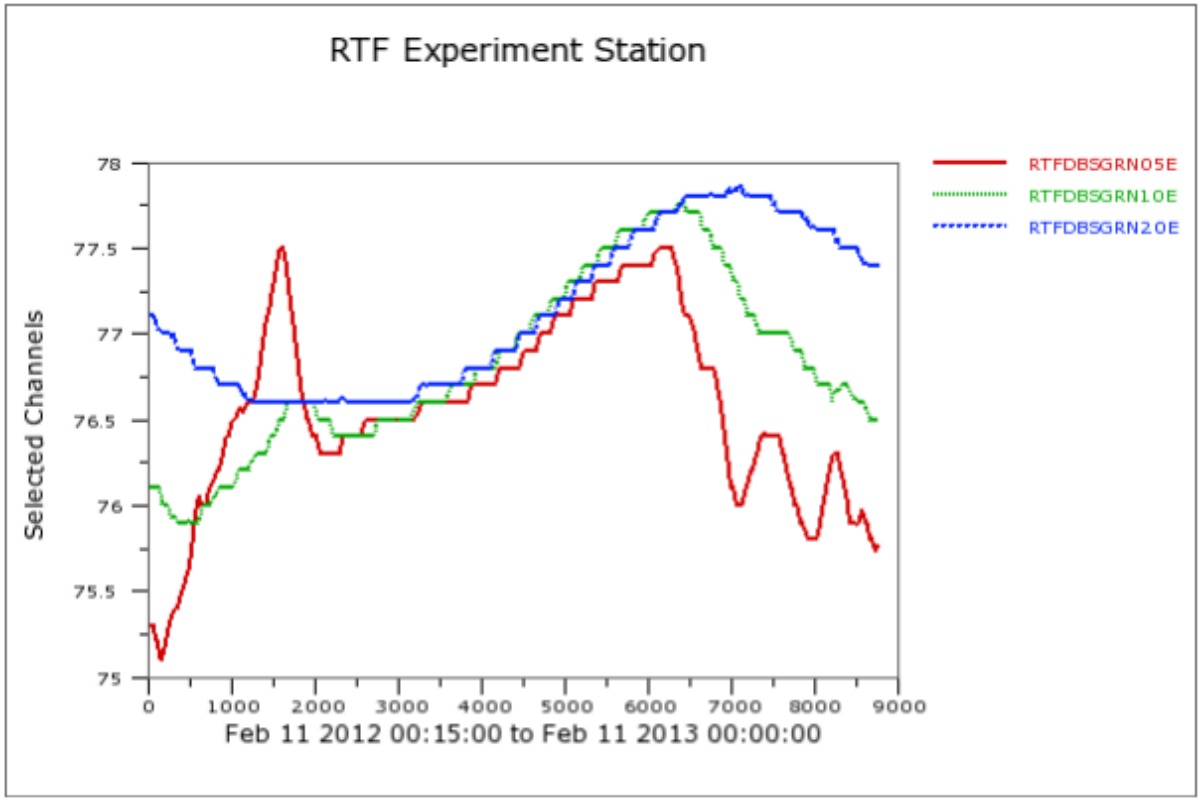




Low Cooling Potential: Center of Slab Temp vs. depth: Deep Grd: 76.8 F

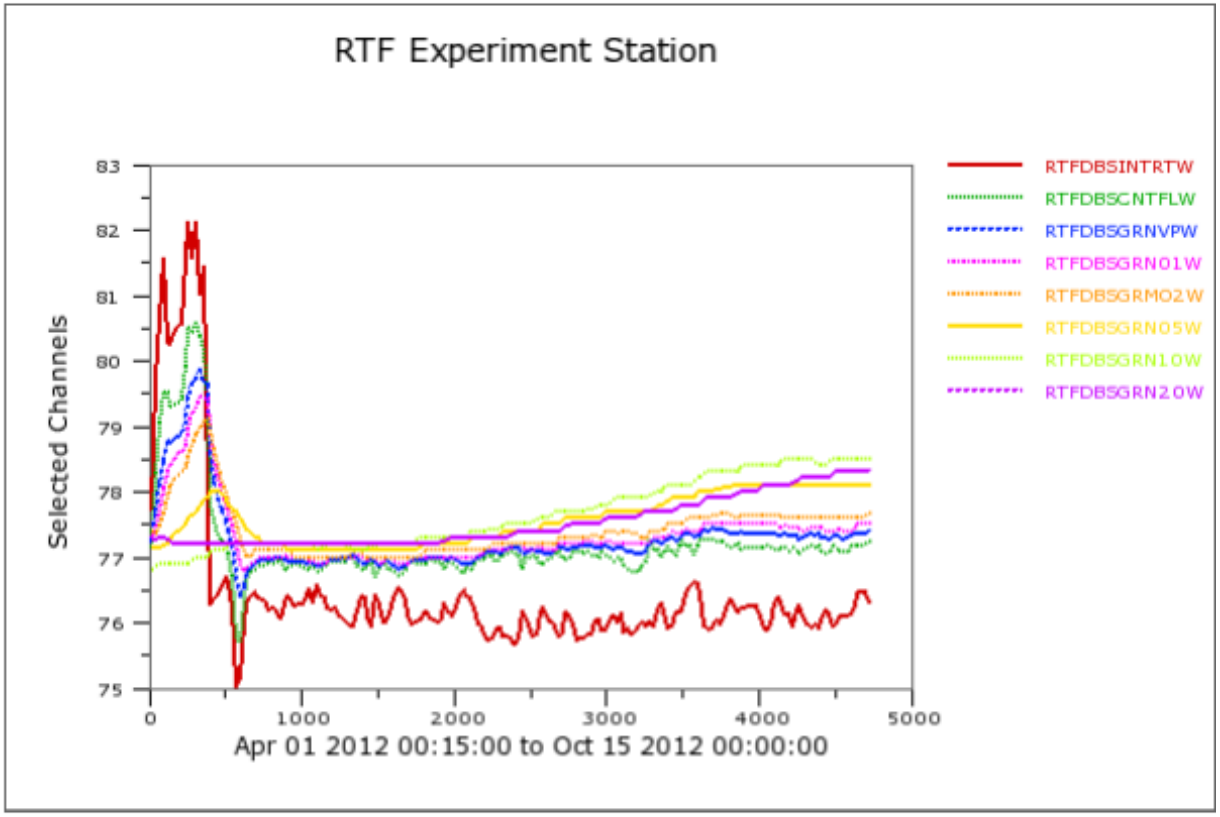
Ground, 5 ft depth (Red)
Ground, 10 ft depth (Green)
Ground, 20 ft depth (Blue)

Note: heat storage at shallow 5 ft depth



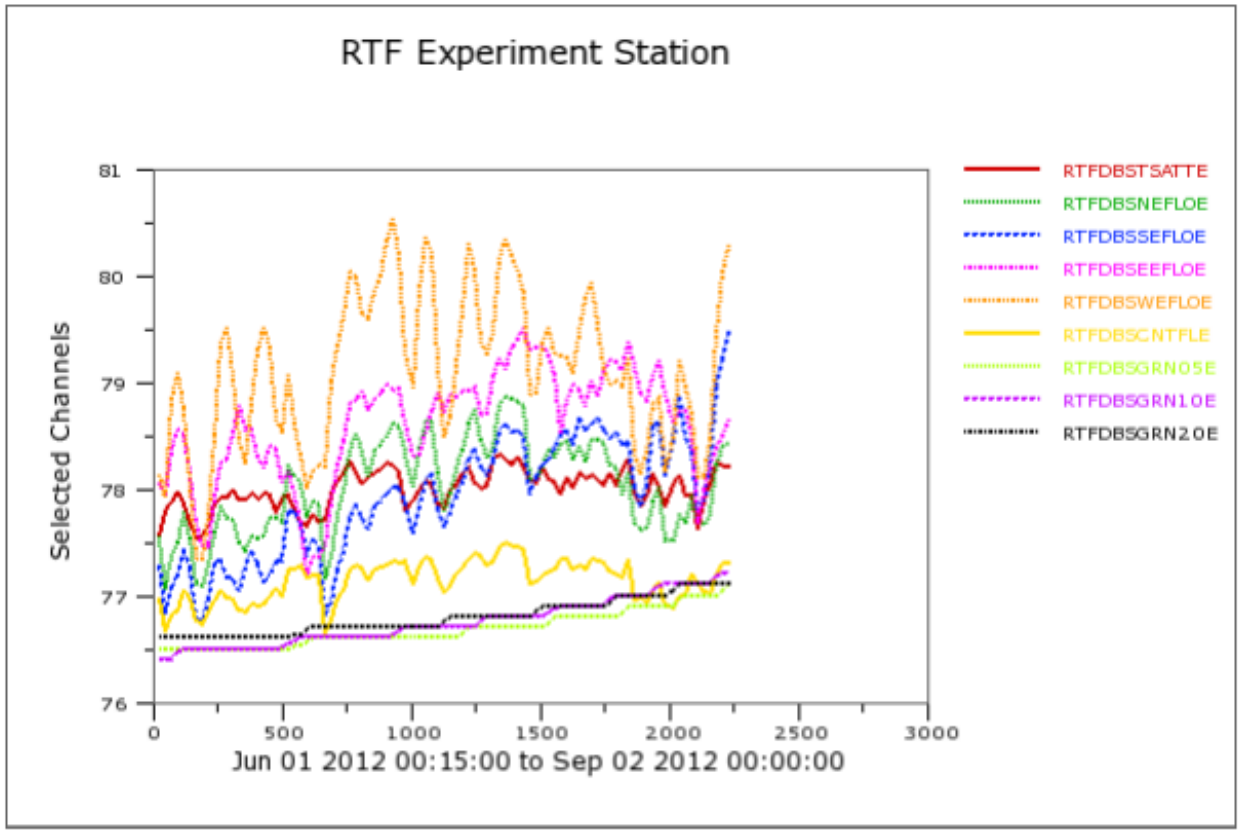
Center of Slab Temperature: Heat Storage before AC

Interior room air temperature: (Red)
Center of slab, surface: (Green)
Slab on the underside: (Blue)
Ground below, 1 ft depth: (Pink)
Ground, 2 ft depth (Orange)
Ground, 5 ft depth (Yellow)
Ground, 10 ft depth (Lime)
Ground, 20 ft depth (Purple)



Edges are less kind in cooling season

Int air temperature: (Red): 78.0 F
N Edge: (Green): 78.0
S Edge: (Blue): 77.9
E Edge: (Pink): 78.6
W Edge (Orange): 79,1
Center (Yellow): 77.1
Grd, 5 ft depth (Lime): 76.7
Grd, 10 ft depth (Purple): 76.7
Grd, 20 ft depth (Black): 76.8



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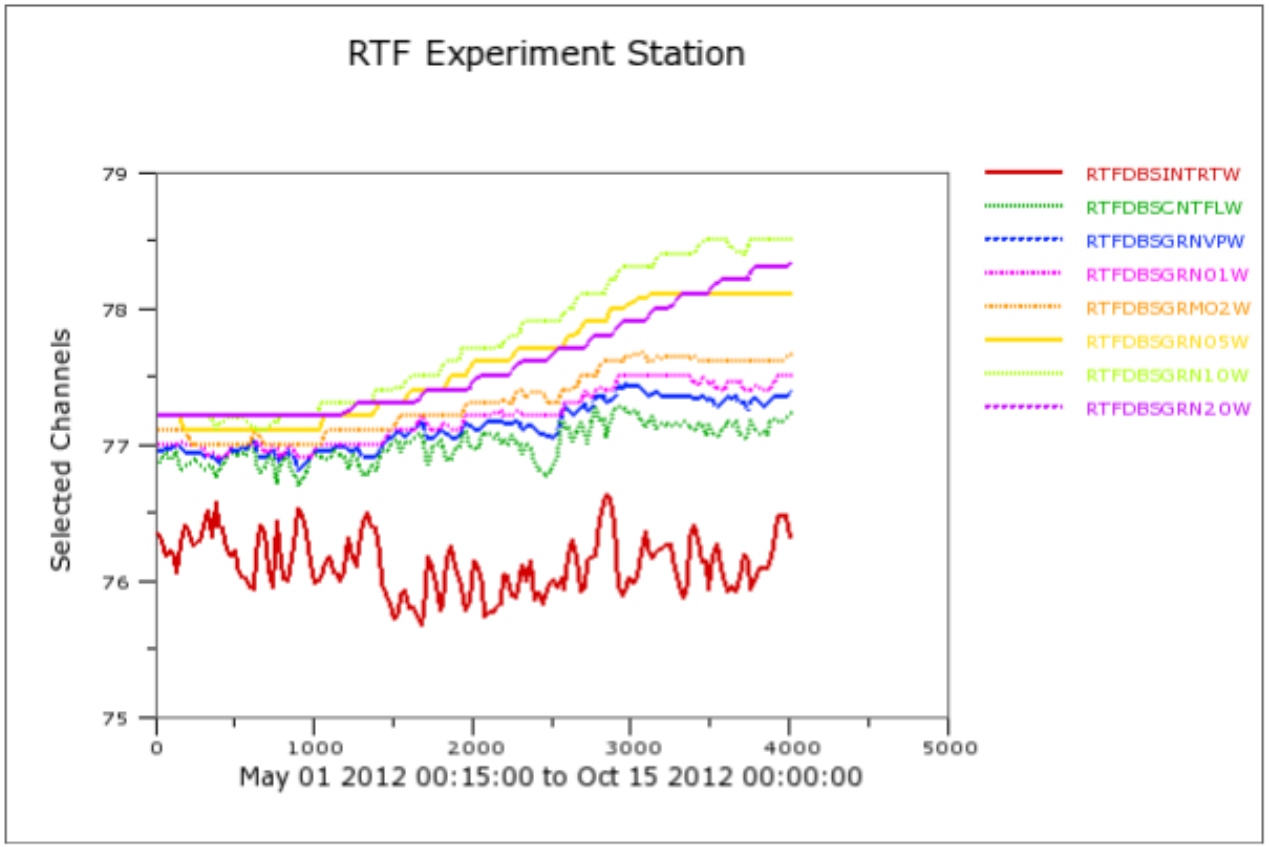
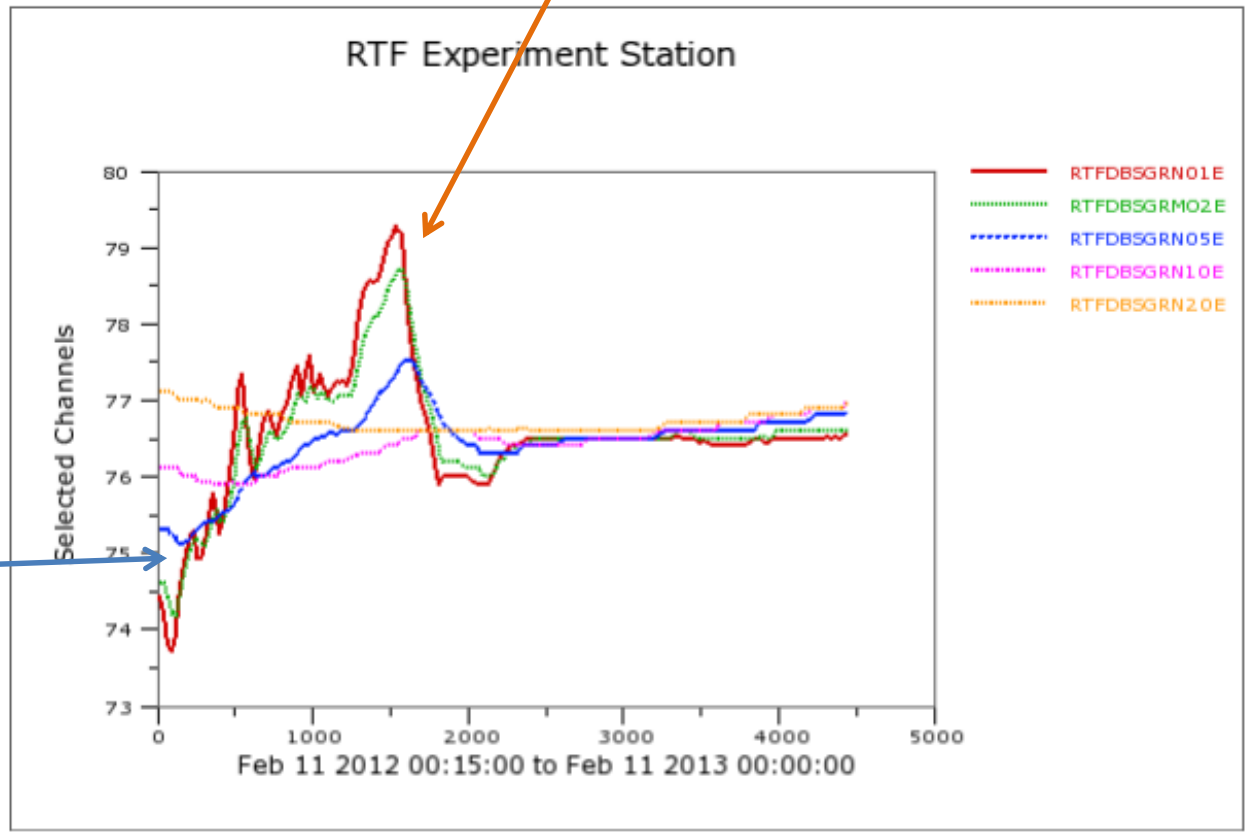


There is heating season advantage…

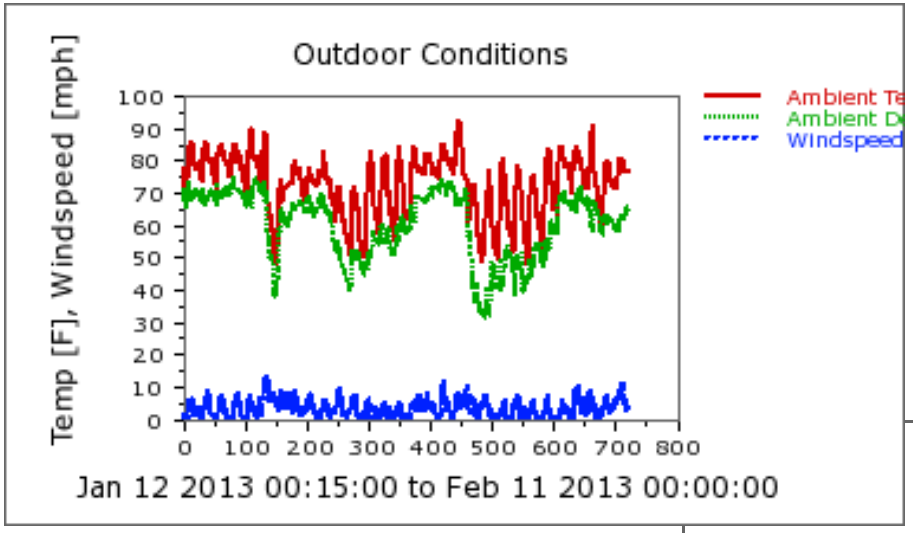
Interior room air temperature: (Red)
Center of slab, surface: (Green)
Slab on the underside: (Blue)
Ground below, 1 ft depth: (Pink)
Ground, 2 ft depth (Orange)
Ground, 5 ft depth (Yellow)
Ground, 10 ft depth (Lime)
Ground, 20 ft depth (Purple)

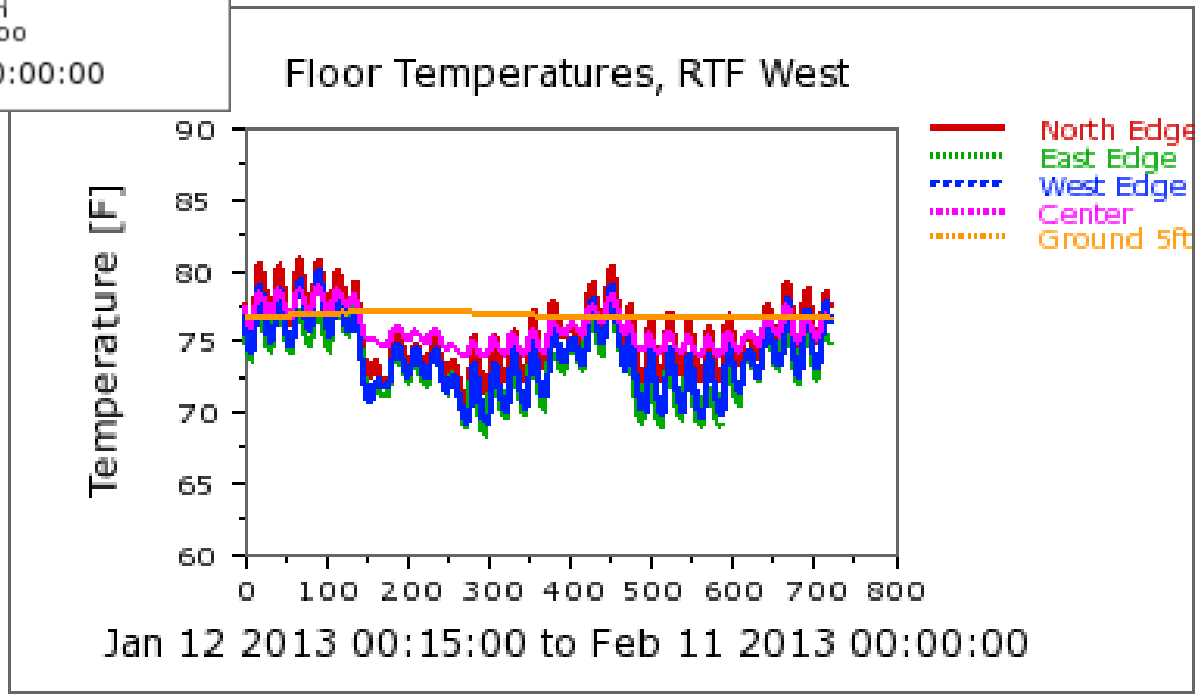
Heat storage before cooling

Heat gains from slab In winter



Florida's Mild Winter…





Soil Properties

Soil diffusivity is estimated at approximately1.03 ft^2/day for the soils under the FRTF buildings. This would represent very wet sandy soils given the classification of Kusuda and Harrington (1982) and the upper end of measured diffusivities described by Kusuda and Achenbach (1965). Given that the soil density was measured at 1325.5 kg/m^3 and specific heat is assumed to be 1000 J/kg.C with some level of wetness, the soil conductivity may be estimated at 1.49 W/m.K (0.86 Btu/hr-ft-F), which is similar to the mid-range for moist sandy soils.

Instruments

Indoor Room Conditions	Type	Accuracy
Temp/Relative Humidity (RH)/Dew Point Vaisala HMP50 Transmitters	Thin-film, dielectric capacitive	0.5°C / 3% RH / 0.8°C[a]
Slab and Ground Conditions		
Temperature: copper-constantan	thermocouple	0.5°C
Energy Use		
Air handler Condenser	pulse watt hr pulse watt hr	0.5% 0.5%
Weather	Type	Stated Accuracy
Outdoor temperature/RH Vaisala HMP50 Transmitters Redundant measurement: Type-T thermocouple in vented gill plate	Thin-film, dielectric capacitive	0.5°C / 3% RH