EPA Vapor Intrusion Workshop

Measurement-Based Methods for Protective & Defensible Chlorinated VI Exposure Determinations

Introduction to Case Study Presentations in a National Context

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Questions for Today

Practical Questions Case Studies Can Address – Temperature and Pressure

- Does the temporal trend of exterior temperature (T) or indoor/outdoor T differential (ΔT) reliably predict volatile organic chemical (VOC) vapor intrusion (VI) in a given structure?
- Does that relationship have the same form/shape in different climates/site/building types?
- Does the temporal trend of measured differential pressure (indoor/outdoor ΔP; subslab/indoor ΔP) reliably predict VOC VI in a given structure?
- How much ΔP variability is typical?
- How much baseline data do you need to understand ΔP drivers for a building?
- Can the ΔP driver be predicted based on observed or forecasted barometric pressure (BP)?

Practical Questions Case Studies Can Address - Radon

- Does the temporal trend of radon (Rn) indoors reliably predict VOC VI in a given structure?
- How much Rn variability is typical?
- How much Rn baseline data do you need to understand a building sufficiently to use Rn to guide VOC sampling times?
- Does the spatial trend of Rn indoors reliably predict VOC VI in a single building? multifamily unit? Large building? Across a neighborhood/plume?
- How much Rn spatial variability is typical?
- Can the attenuation factor of Rn in soil gas (exterior or sub-slab) be used to accurately estimate the indoor conc. of VOC when Rn & VOC were both simultaneously collected from the same near building soil gas?

Case Studies

Sites Providing Large/Long Term Data Sets across the IECC Climate Zones – 2012 IEC

Wendell and Gaffney AK -8

Bradford VT – 6A

CRREL (NH) – 6A

Redfield – 5B and Colorado DOT

SE WI - 6

Indianapolis Duplex, SEND/Wheeler – 5A

Sun Devil Manor UT - 5B

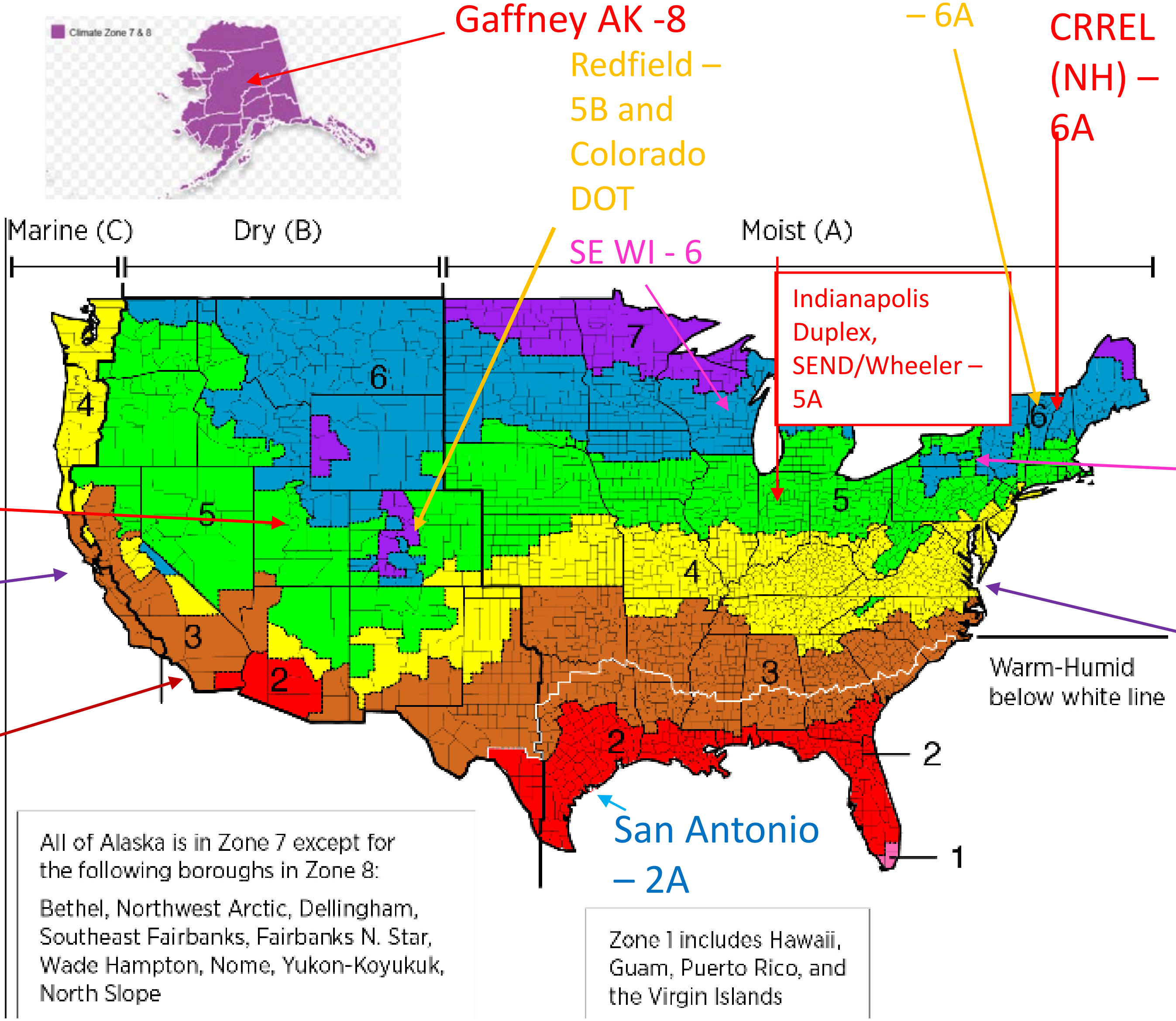
Endicott NY – 6A

MEW and Moffett Field CA – 3C

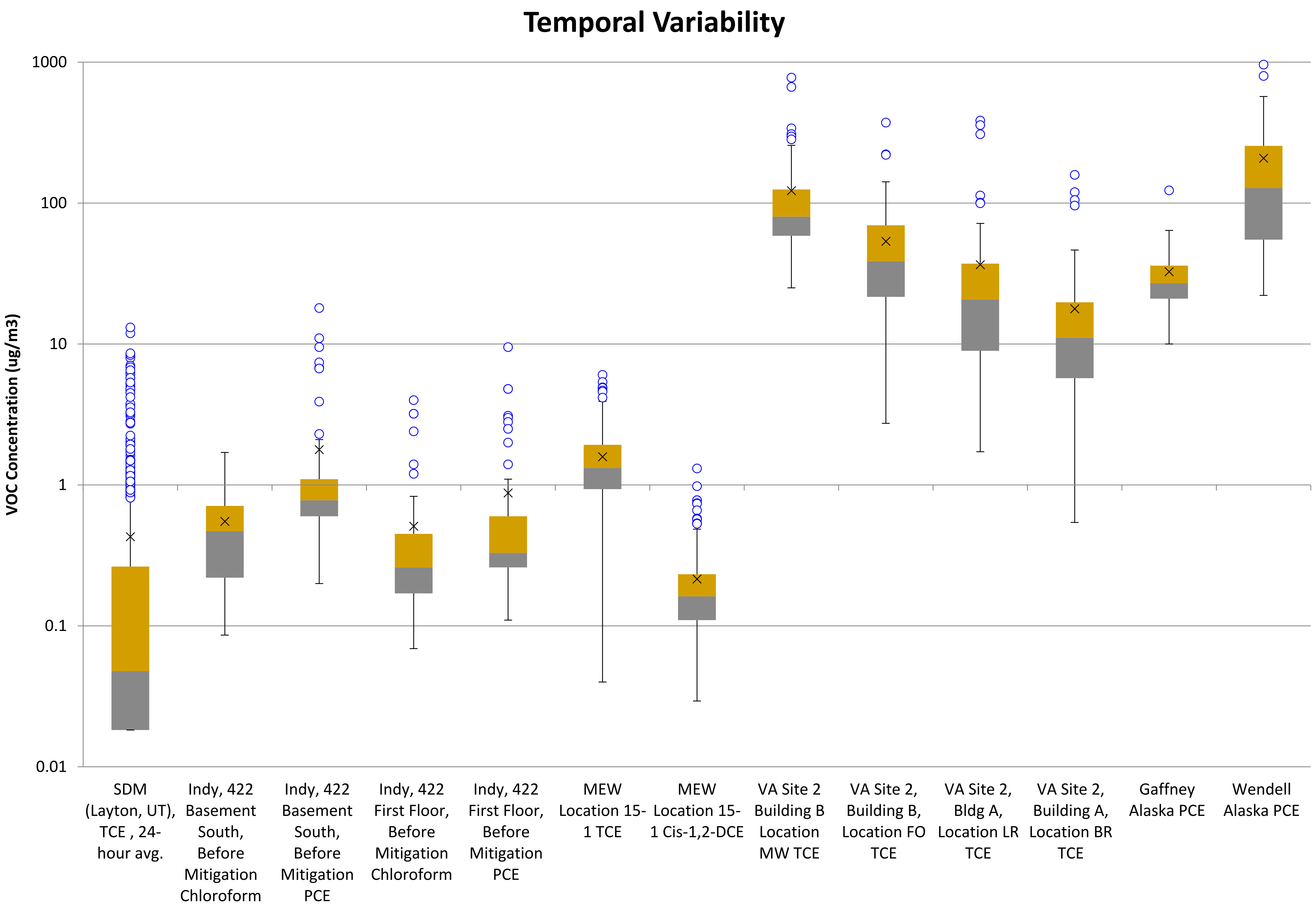
VA Military Sites A and B – 3A

North Island San Diego – 3C

San Antonio – 2A



IECC zones Reprinted form https://basc.pnnl.gov/images/iecc-climate-zone-map


Temporal Variability
VOC Concentration (ug/m3)
1000
100
10
1
0.1
0.01
SDM (Layton, UT), TCE , 24-hour avg.
Indy, 422 Basement South, Before Mitigation Chloroform
Indy, 422 Basement South, Before Mitigation PCE
Indy, 422 First Floor, Before Mitigation Chloroform
Indy, 422 First Floor, Before Mitigation PCE
MEW Location 15-1 TCE
MEW Location 15-1 Cis-1,2-DCE
VA Site 2 Building B Location MW TCE
VA Site 2, Building B, Location FO TCE
VA Site 2, Bldg A, Location LR TCE
VA Site 2, Building A, Location BR TCE
Gaffney Alaska PCE
Wendell Alaska PCE

US Population of Buildings

Size Characteristics of US Commercial Buildings (2003)

Building Floorspace (square feet)	Number of Buildings (%)	Total Floorspace (%)
1,001 to 5,000	53	10
5,001 to 10,000	20	10
10,001 to 25,000	17	18
25,001 to 50,000	5	13
50,001 to 100,000	3	14
100,001 to 200,000	2	14
200,001 to 500,000	1	10
Over 500,000	0	11

Census Bureau/Energy Information Agency data, converted to percentages
https://www2.census.gov/library/publications/2011/compendia/statab/131ed/tables/12s1006.pdf

Age Distribution of US Commercial Buildings as of 2003

	Number of Buildings (%)	Total Floorspace (%)
Year Constructed		
Before 1920	7	5
1920 to 1945	11	10
1946 to 1959	12	10
1960 to 1969	12	12
1970 to 1979	16	17
1980 to 1989	16	17
1990 to 1999	19	20
2000 to 2003	7	9

Data from:
https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html; converted to percentages

How Common are Unheated Commercial Buildings?

	Number of Buildings (percentage)				Total Floorspace (percentage)			
	Not Heated	1 to 50 Percent Heated	51 to 99 Percent Heated	100 Percent Heated	Not Heated	1 to 50 Percent Heated	51 to 99 Percent Heated	100 Percent Heated
All Buildings*	14	11	11	64	7	11	13	70
Census Region								
Northeast	7	10	12	71	2	11	12	75
Midw est	12	9	11	67	4	7	10	79
South	18	13	9	60	11	12	12	65
West	16	11	12	61	11	13	17	59
Clim ate Zone: 30-Year Average								
Under 2,000 CDD and --								
More than 7,000 HDD	12	11	11	65	5	10	13	72
5,500-7,000 HDD	10	9	10	71	4	6	10	80
4,000-5,499 HDD	7	13	12	68	2	12	15	71
Few er than 4,000 HDD	18	11	12	59	11	12	15	62
2,000 CDD or More and --								
Few er than 4,000 HDD	26	13	9	53	17	15	10	58

(Data from 2003 Energy Information Agency Survey) – Percentages calculated by Lutes
https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

How Common Is Air Conditioning in US Commercial Buildings?

	Number of Buildings (percentage)				Total Floorspace (percentage)			
	Not Cooled	1 to 50 Percent Cooled	51 to 99 Percent Cooled	100 Percent Cooled	Not Cooled	1 to 50 Percent Cooled	51 to 99 Percent Cooled	100 Percent Cooled
All Buildings*	22	21	14	43	12	26	20	42
Census Region								
Northeast	29	25	13	33	15	33	24	28
Midw est	24	23	16	37	15	28	22	35
South	17	21	11	52	8	21	17	54
West	24	16	16	44	12	23	22	43
Climate Zone: 30-Year Average								
Under 2,000 CDD and --								
More than 7,000 HDD	32	24	14	30	20	29	22	29
5,500-7,000 HDD	25	21	16	39	16	27	21	36
4,000-5,499 HDD	14	29	14	44	5	30	29	37
Few er than 4,000 HDD	21	17	13	49	11	22	18	49
2,000 CDD or More and --								
Few er than 4,000 HDD	13	18	11	57	7	20	13	61

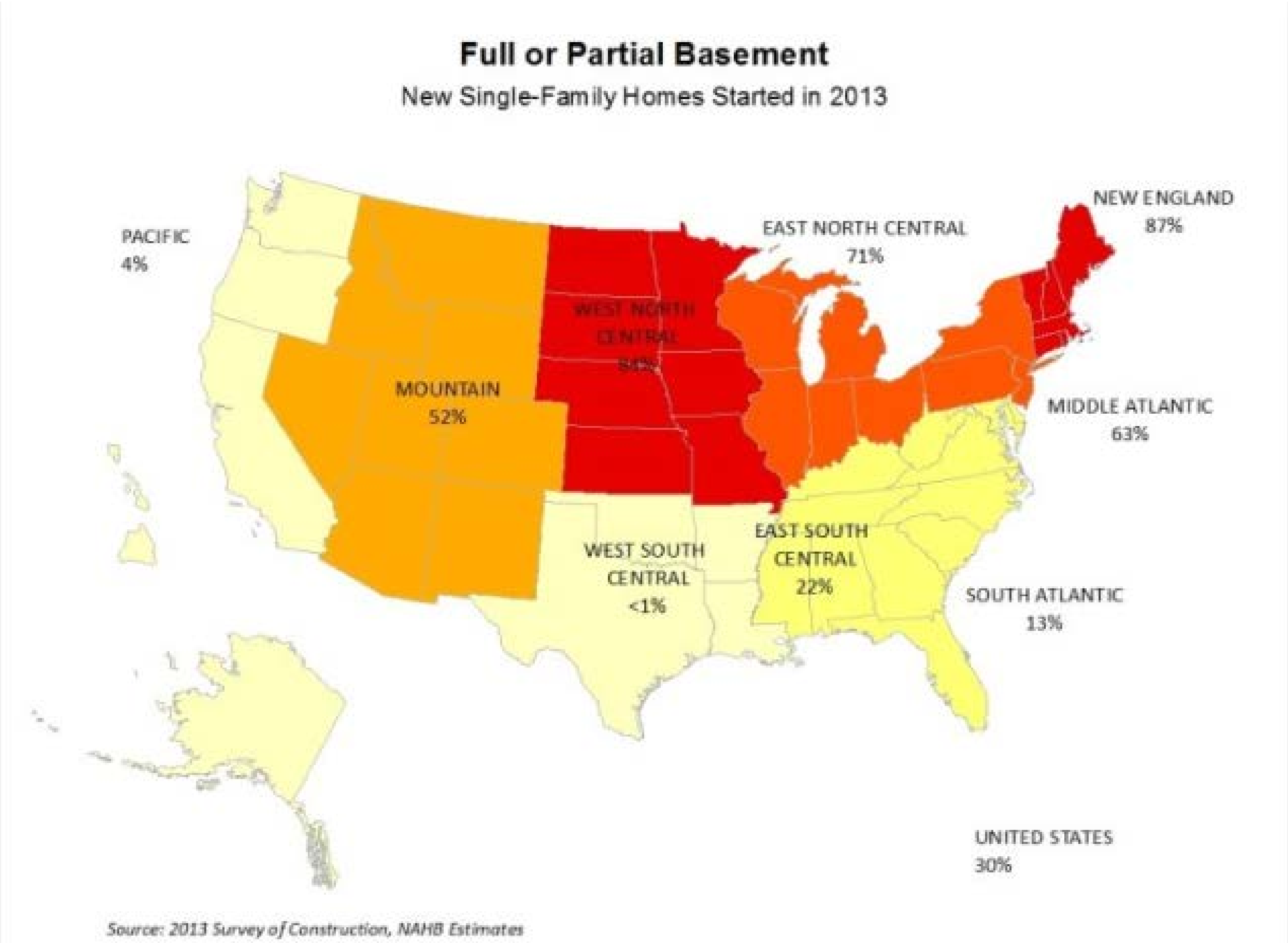
(Data from 2003 Energy Information Agency Survey) – Percentages calculated by Lutes
https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

How Common Are Various Heating Systems in US Commercial Buildings? - 2003

Number of Buildings (percentage)								
		Heating Equipment (more than one may apply)						
All Buildings*	Heated Buildings	Heat Pumps	Furnaces	Individual Space Heaters	District Heat	Boilers	Packaged Heating Units	Other
100	86	10	40	18	1	12	21	4
Primary Space-Heating								
Energy Source								
Electricity	27	8	6	7		1	9	1
Natural Gas	43	2	26	8		8	10	1
Fuel Oil	6		3	1		3		
District Heat	1	0		0	1		0	
Propane	7		4	2			1	
Other	2							

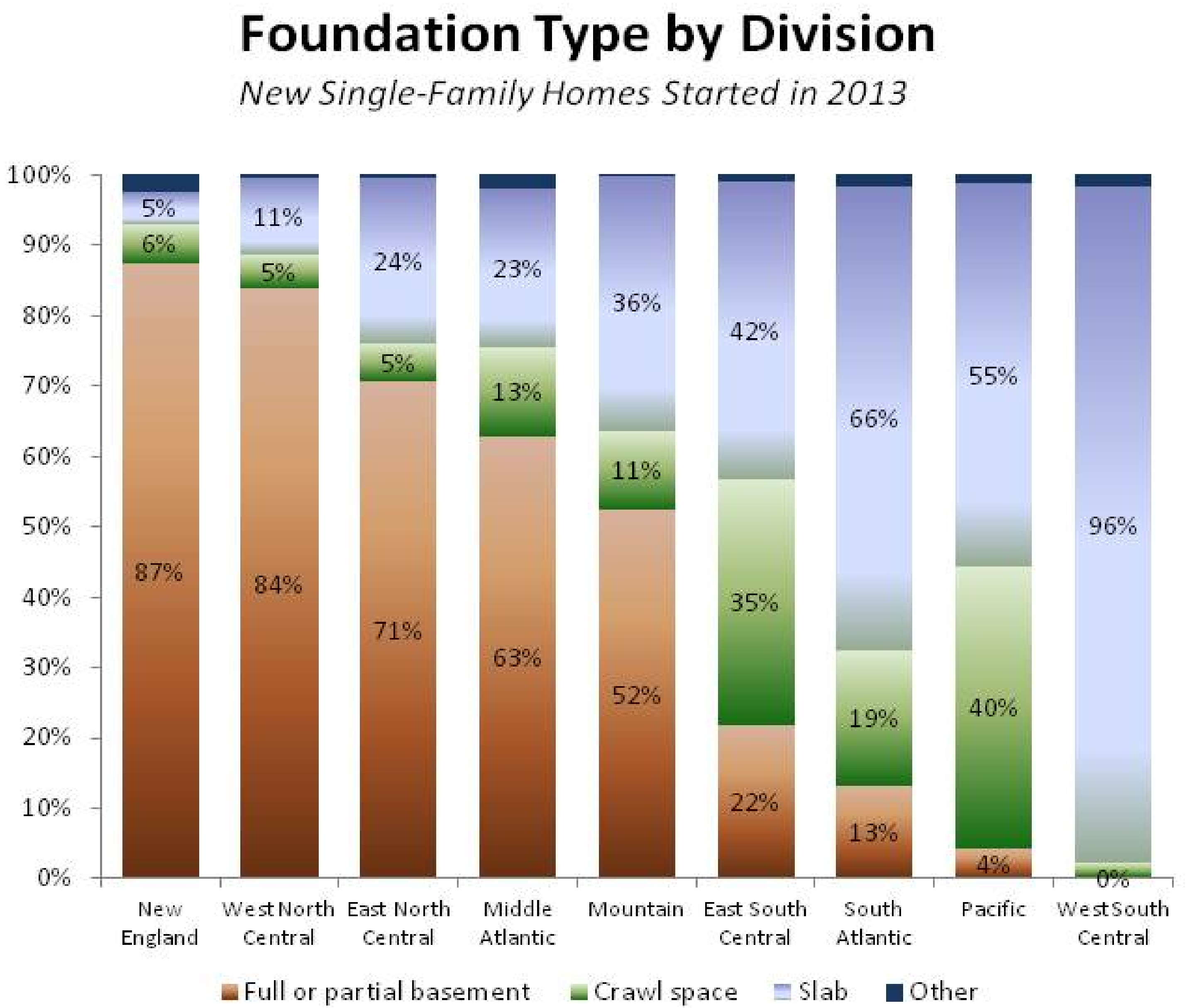
(Data from 2003 Energy Information Agency Survey) – Percentages calculated by Lutes
https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

Basement Percentage Varies Dramatically By Region in New US Residences



National Association of Homebuilders: http://eyeonhousing.org/2014/10/what-foundations-are-built-across-the-nation/

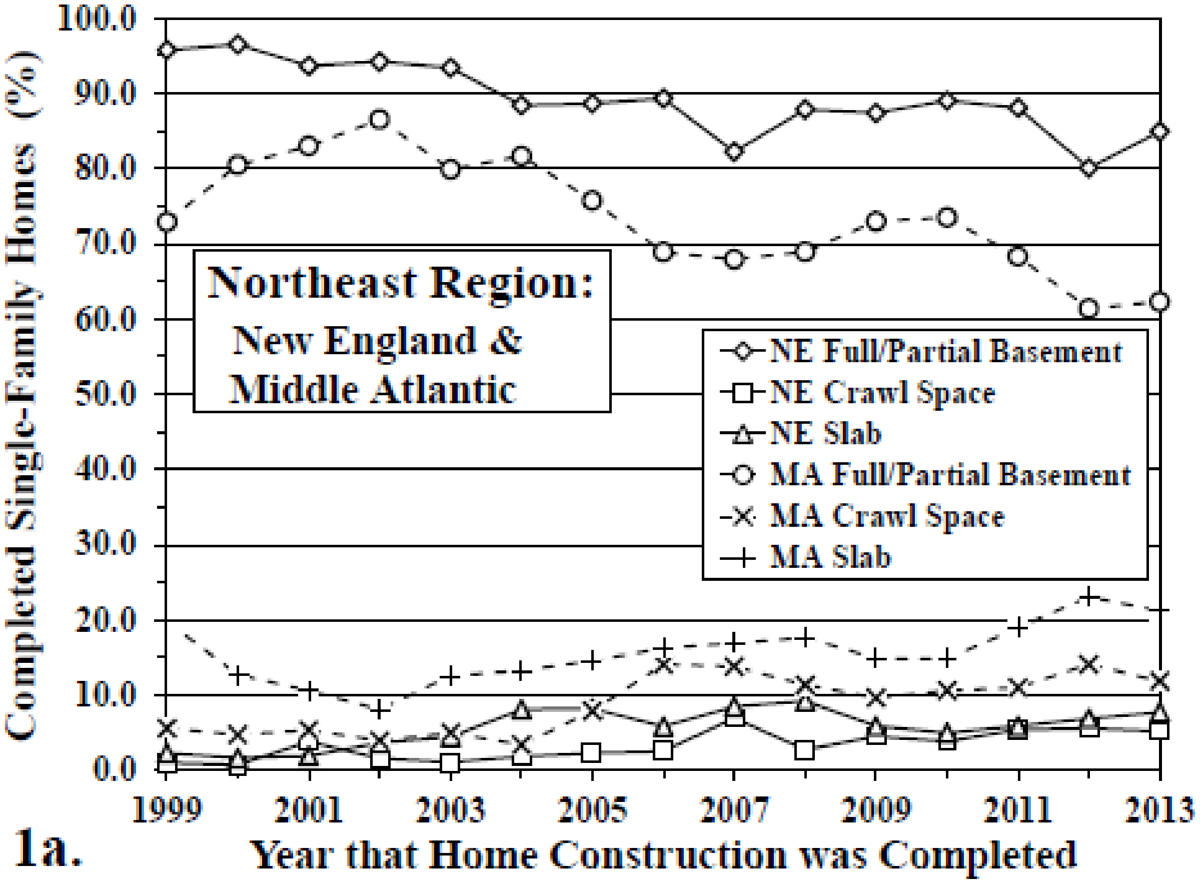
Foundation Type Varies with Region

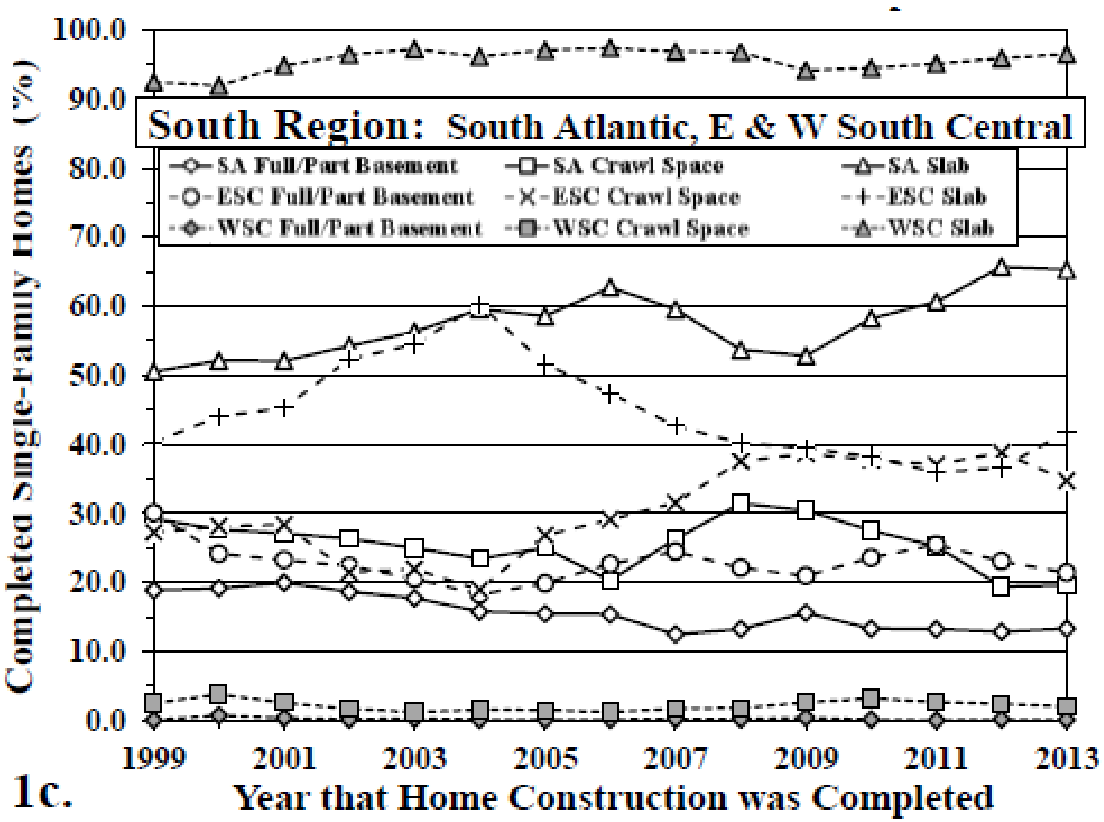


Source: Survey of Construction, 2013, NAHB Estimates

National Association of Homebuilders: http://eyeonhousing.org/2014/10/what-foundations-are-built-across-the-nation/

Historical Trends in US Residential Foundation Types

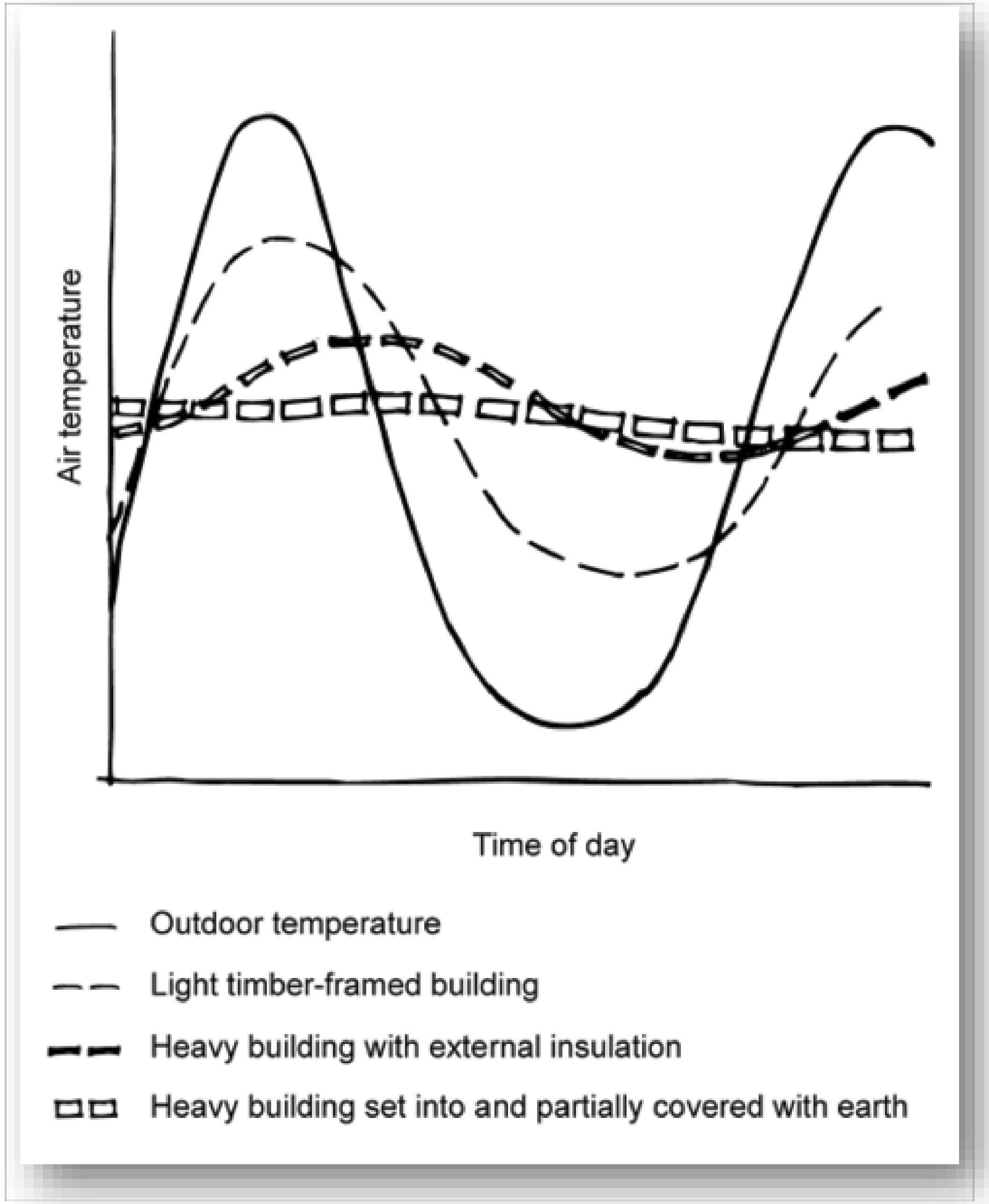




Reprinted from Bradtmueller J.P. et. all. 2015 "A Comparison of House Size and Foundation Type for U.S. Residential Homes"
51st ASC Annual International Conference Proceedings
http://ascpro0.ascweb.org/archives/cd/2015/paper/CEGT411002015.pdf

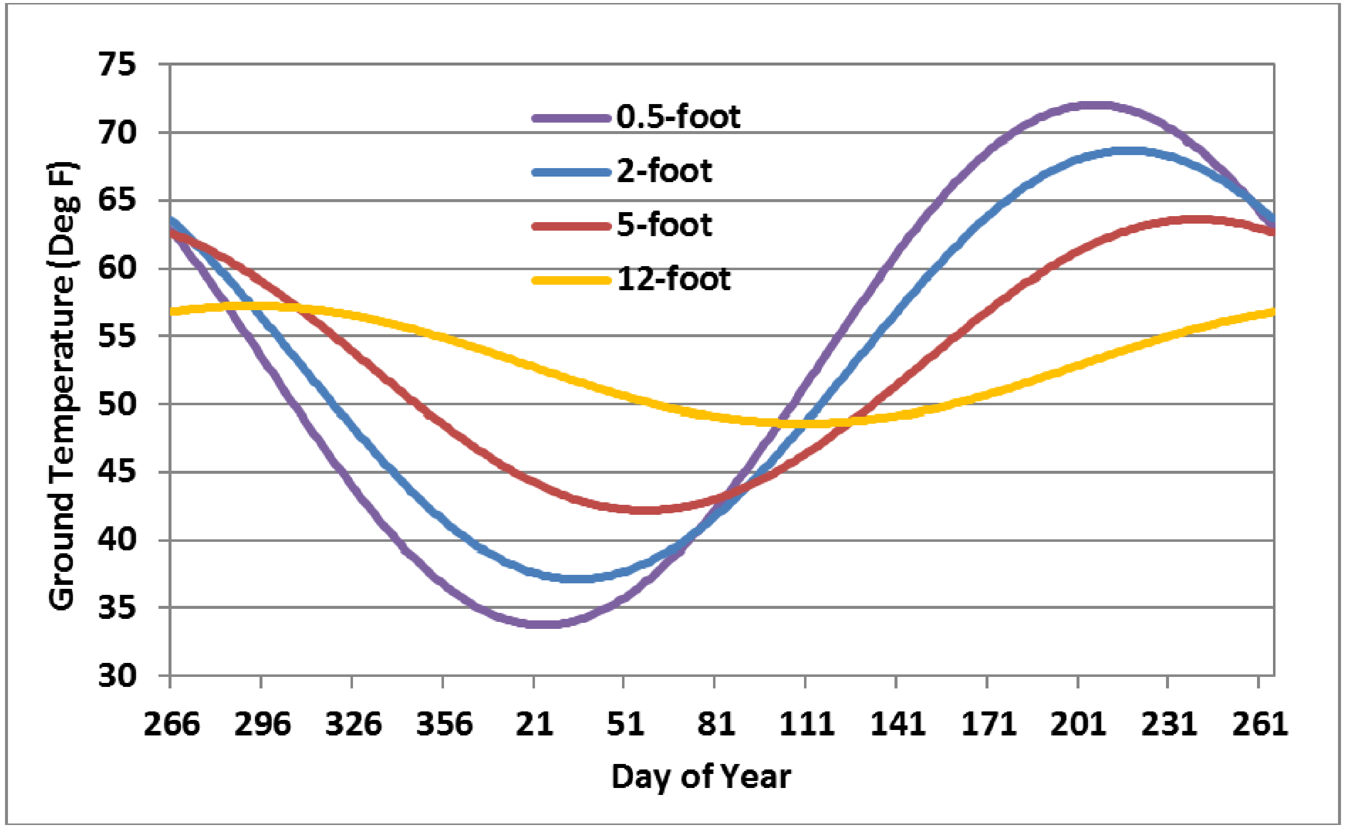
Some Key Concepts

The Importance of Thermal Mass



Diurnal cycle in Buildings

Annual Cycle in Soil



Above Graphic from: https://igws.indiana.edu/Geothermal/HeatPumps

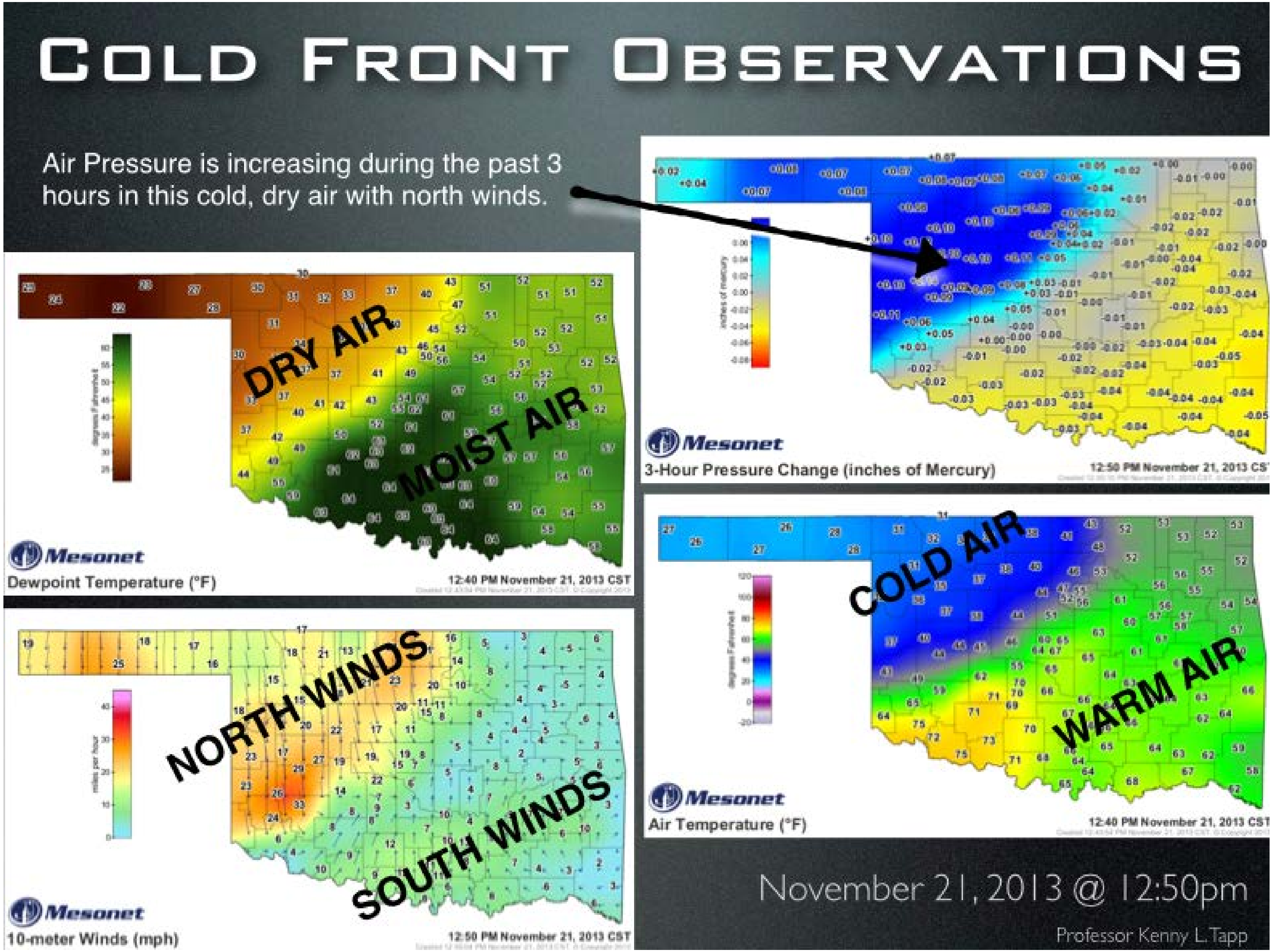
Left Graphic from: http://www.yourhome.gov.au/passive-design/thermal-mass

Temperature, Pressure and Precipitation Events are All Linked When a Front Passes

During a Cold Front passage:

- Air Temperature **Decreases**
- Dewpoint Temperature (Moisture) **Decreases**
- Wind shift from South to North
- Air Pressure **Increases**

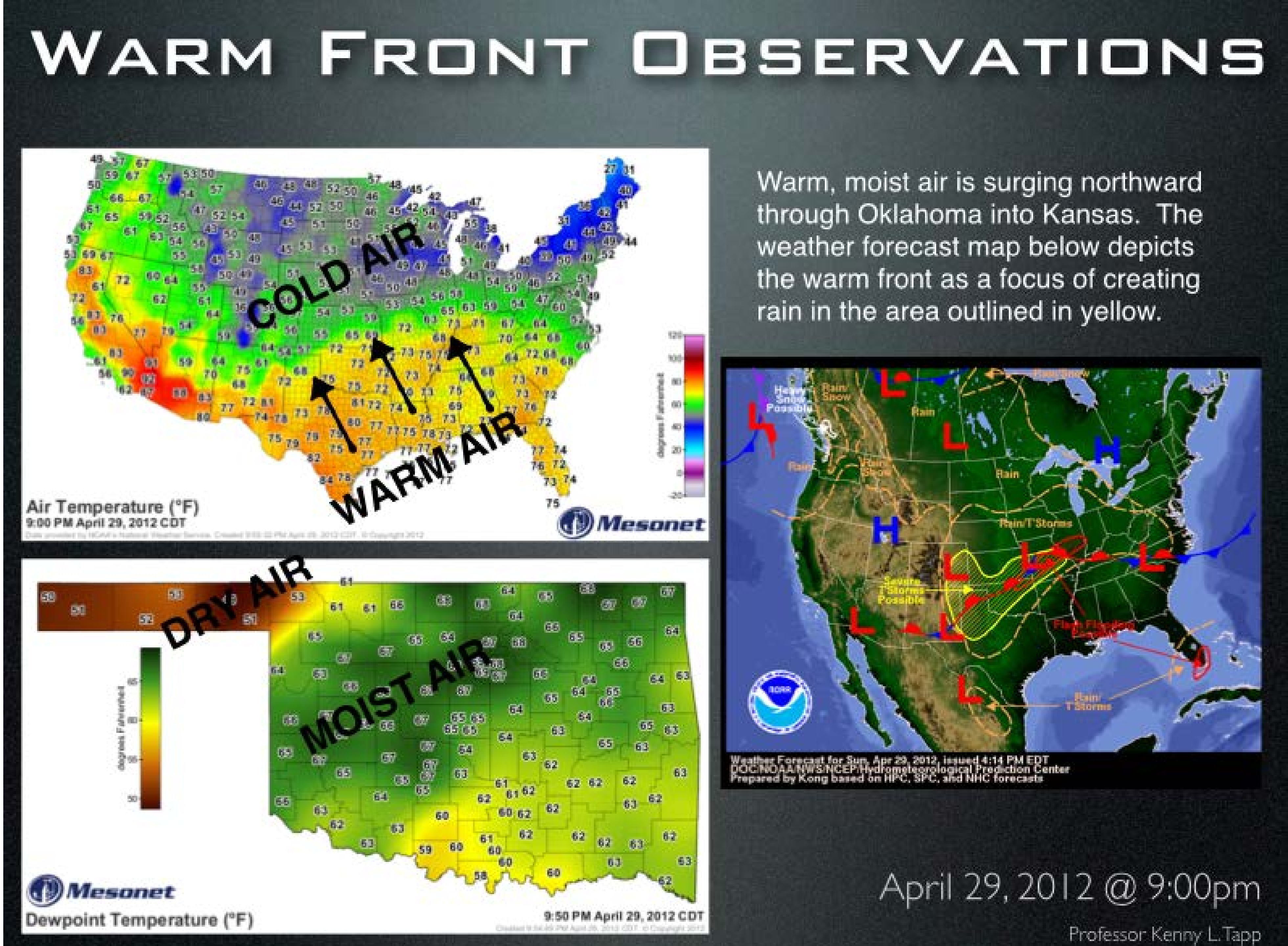
Reprinted from:
http://www.occc.edu/ktapp/gophysics/PHYS1014/AirMassFronts.htm
(Oklahoma City Communit College)



Temperature, Pressure and Precipitation Events are All Linked When a Front Passes during a Warm Front passage:

- Air Temperature **Increases**
- Dewpoint Temperature (Moisture) **Increases**
- Air Pressure **Decreases**

Reprinted from: http://www.occc.edu/ktapp/gophysics/PHYS1014/AirMassFronts.htm (Oklahoma City Communit College)



Review Paper Published, Reprints Available on Request from Authors

- Schuver, H.J., C. Lutes, J. Kurtz, C. Holton and R.S. Truesdale "*Chlorinated vapor intrusion indicators, tracers, and surrogates (ITS): Supplemental measurements for minimizing the number of chemical indoor air samples—Part 1: Vapor intrusion driving forces and related environmental factors*", Remediation Journal, Published on line June 6, 2018, Volume 38, Issue 3; p 7-31.