Applied Computer Modeling for Building Engineering

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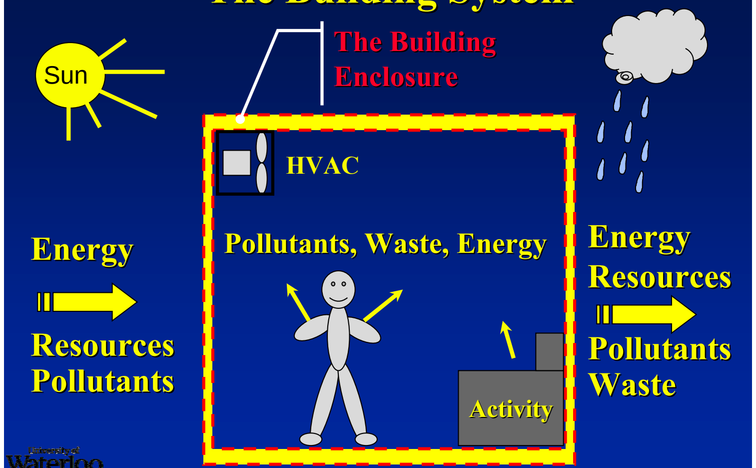
Overview

- Why Modeling?
- Heat Flow
  - Therm / Frame
  - Heat 2D / Heat 3D
  - Case studies
- Heat & Moisture
  - WUFI-ORNL & Validation
  - Case studies
- Fire Energy and Lighting
- Summary

The Building System



Pollutants: Moisture, odour, + +

Modeling for fun and profit

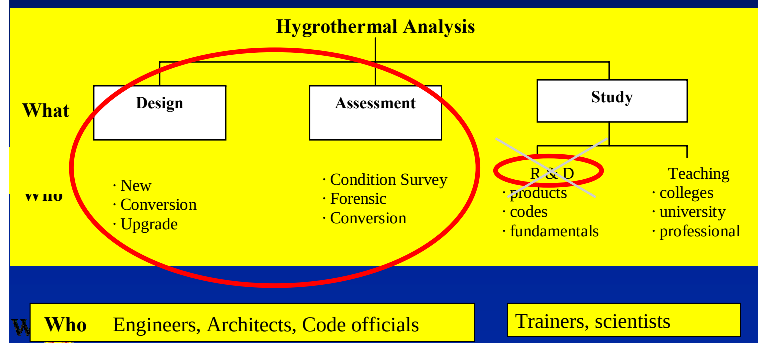
- Predict and understand temperature and moisture condition in & on bldg enclosure
- Avoid design errors
- Understand problems
- Aid the design of repairs
- Development of new systems/products
- Develop understanding of performance (teach)

What are "Models"

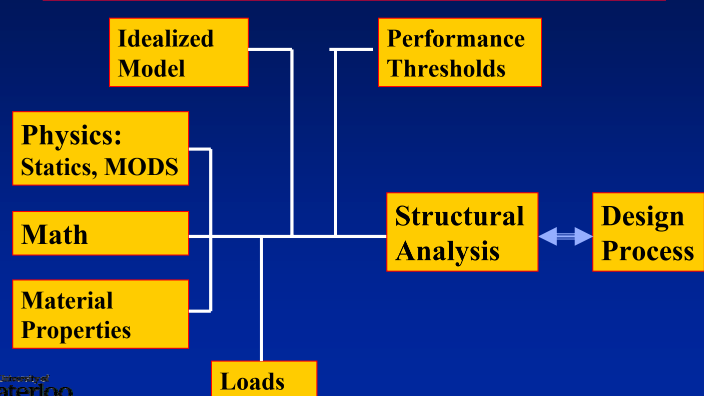
- By definition, an approximation of reality
- Typically a model is designed for a particular purpose,
  - e.g. calculate energy
- As simple as
  - Q= U •ΔT → Q(t) = U •ΔT(t)
- As complex as full building dynamic simulation including occupant behaviour, plant, controls, etc.

What and for Whom?

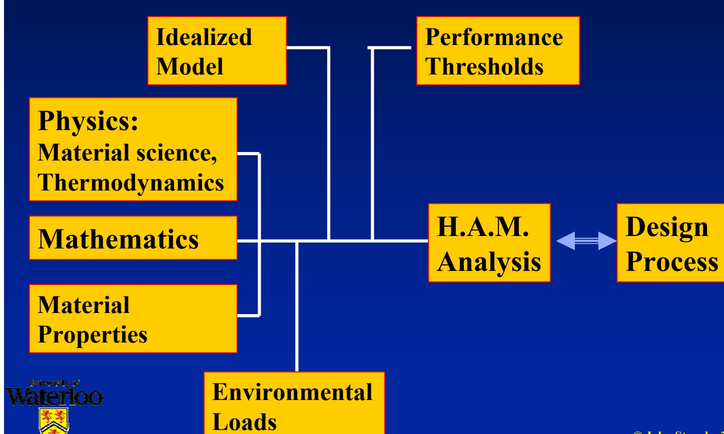
This presentation deals with design & analysis uses



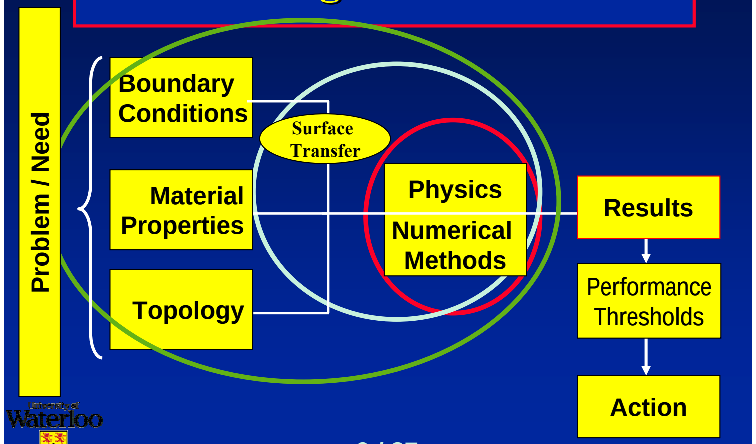
Structural Engineering



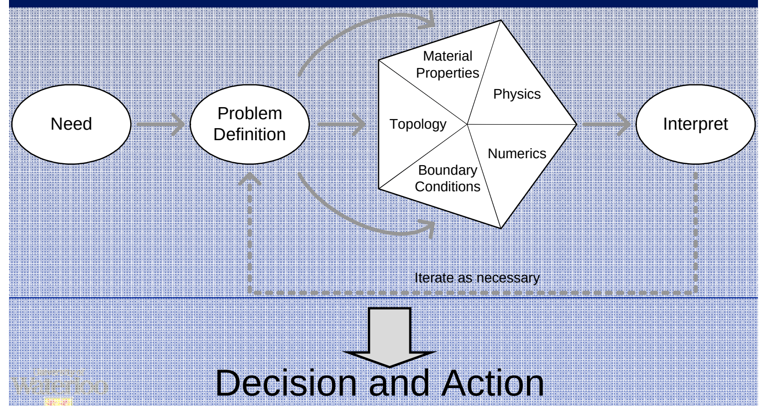
"Building Science" Engineering



Building the "Model"



The Process



Requirements

- Vary with Need, Time available, expertise

- Geometry (topology)
- Boundary Conditions (operating conditions)
- Material Properties
- Physics
- Performance Thresholds

What to Model

- Heat
  - Flow (Energy)
  - Temperatures
- Air
  - Energy
  - Contaminant transport
- Moisture
  - Durability, mold
- Light
- Fire

Heat Flow

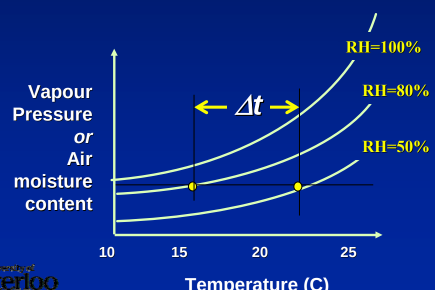
- Steady-state or Dynamic
  - steady-state -- for average conditions or for lightweight construction
  - Dynamic -- to assess thermal mass, transient conditions
- One- Two- or Three-dimensional
- Free Tools
  - Use Therm or Frame
- Both 2-D steady-state

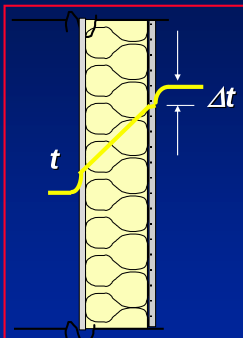
Thermal Bridging

- Why calculate?
  - Heat Loss calculations
  - Surface Condensation
    - dust marking
    - mould
    - windows
  - Interstitial Condensation
- 2-D steady state is easy
- 2-D dynamic acceptable
- 3-D is time consuming

Wall Temperatures and RH

Poor insulation
= cold surface
= high RH





Temperature Profile

Interior Air at 22 C

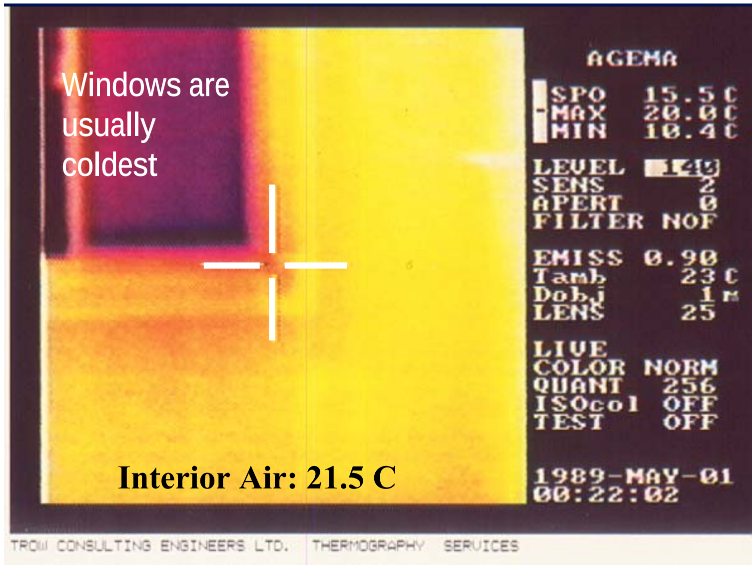
Surface temperatures cannot be less than:

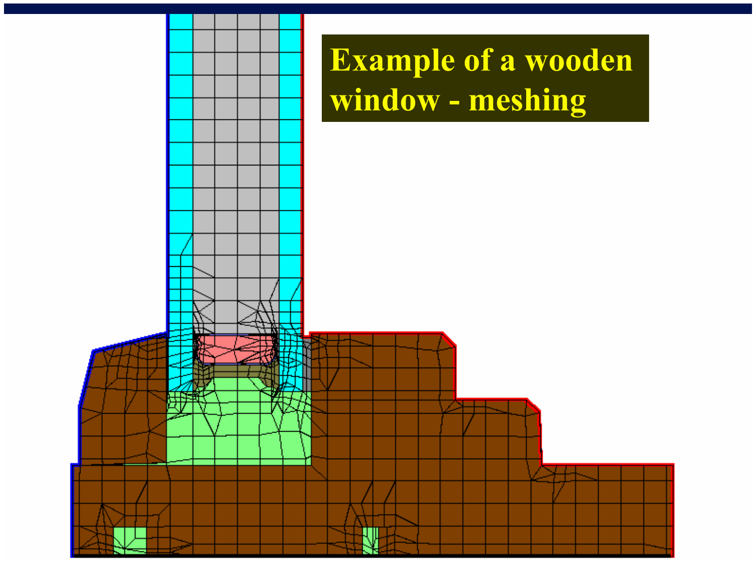
Interior RH	Condensation Temperature	Temperature @80%RH
20	-2	1
40	8	11
50	11	14
60	14	17
80	18	22

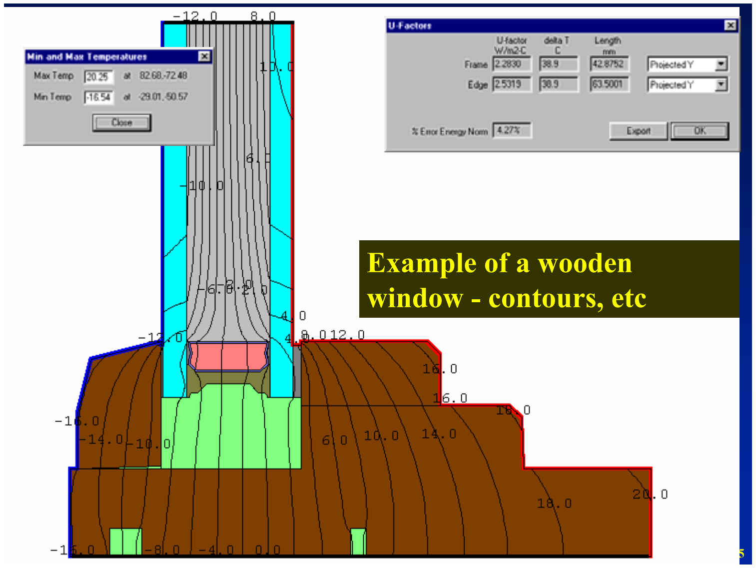
Two-D Steady-state

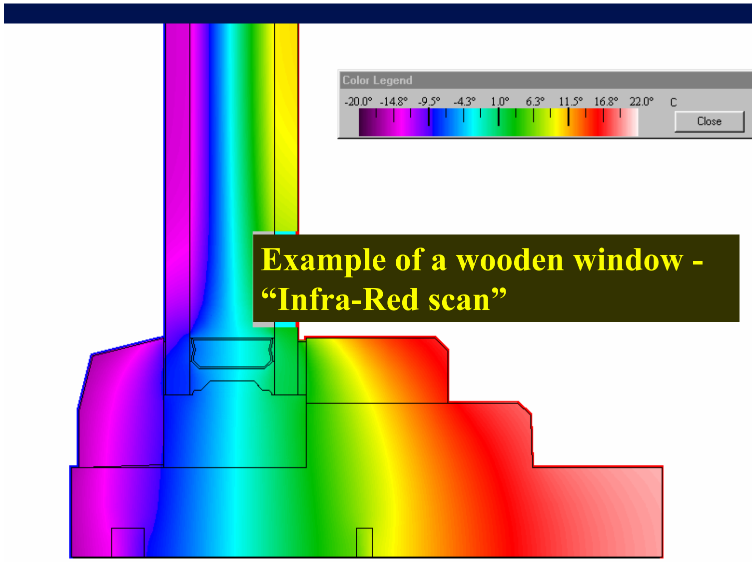
- Frame (www.enermodal.com)
- Therm (windows.lbl.gov/software/therm)
  - Free, downloadable
  - Can use AutoCad templates
  - Primary intent -- window energy calculations
  - Can do much more

University of Waterloo







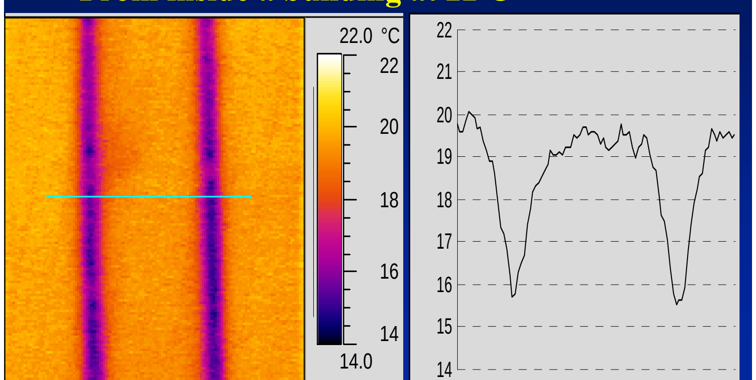


Steel Framing

- Metal Building Systems and Steel Studs
- Can be Thermal Bridges
  - Consume Energy
  - cause dust marking
  - Surface condensation
- How much/little insulation is needed?

Infra-Red Photos

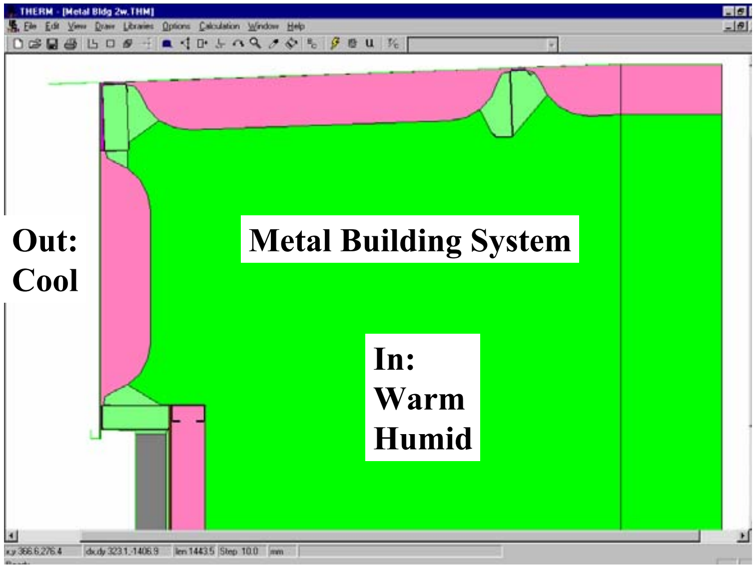
From inside a building at 22 C

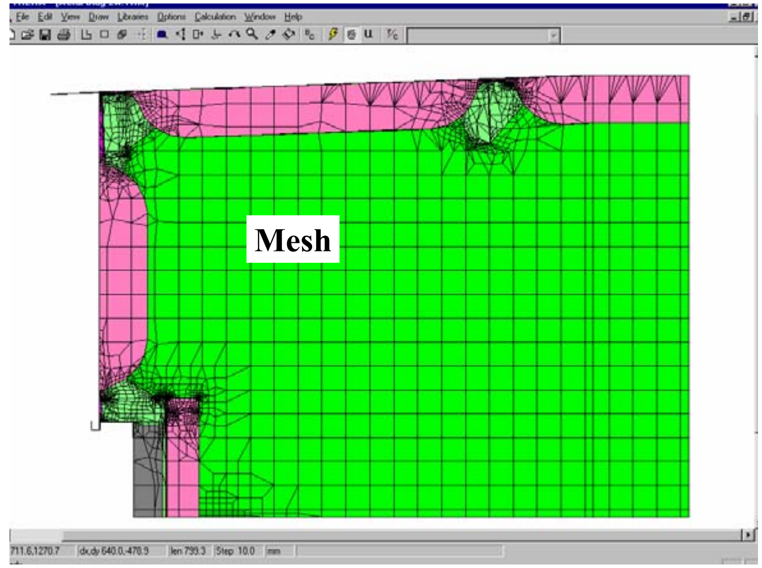


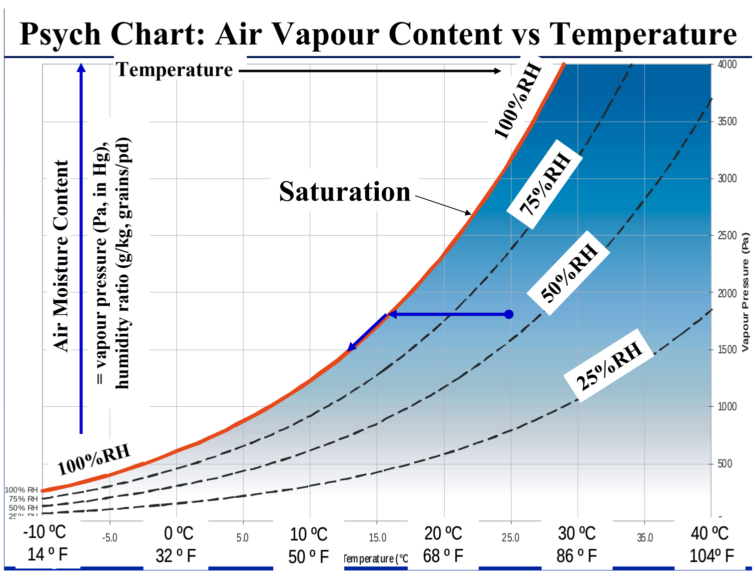
Mixing Models

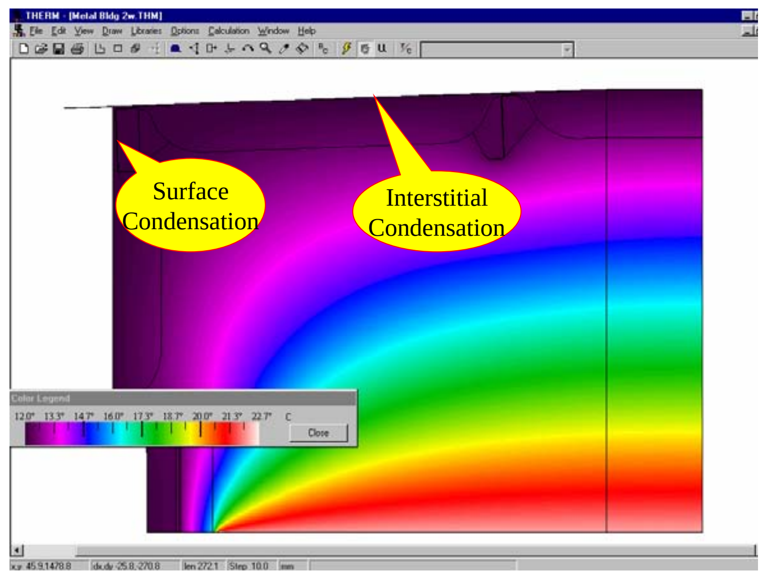
- One model or modeling approach
- e.g.Temperature flow, combined with dewpoint
- “suite of models”
  - range of complexity/accuracy
  - range of expertise required

Case Study Major manufacturing plant
  - High interior humidity for film production


Out:
Cool
Metal Building System
In:
Warm
Humid

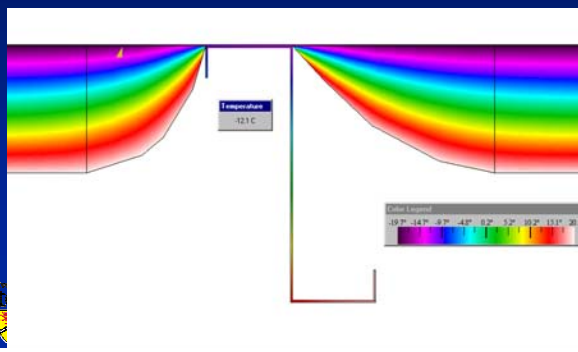

Mesh


Psych Chart: Air Vapour Content vs Temperature
Temperature
Air Moisture Content
= vapour pressure (Pa, in Hg),
humidity ratio (g/kg, grains/pd)
Saturation
100%RH
75%RH
50%RH
25%RH
100%RH
-10 ºC
14 º F
0 ºC
32 º F
10 ºC
50 º F
20 ºC
68 º F
30 ºC
86 º F
40 ºC
104º F

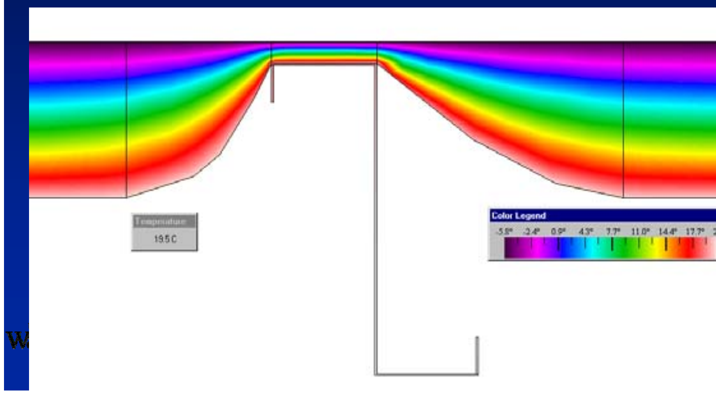

Surface
Condensation
Interstitial
Condensation

Case Study- Rec. Complex

- Metal building system
- Condensation and Dripping?



- Add ¾” insulation block
- Zero risk
- Now – other building details

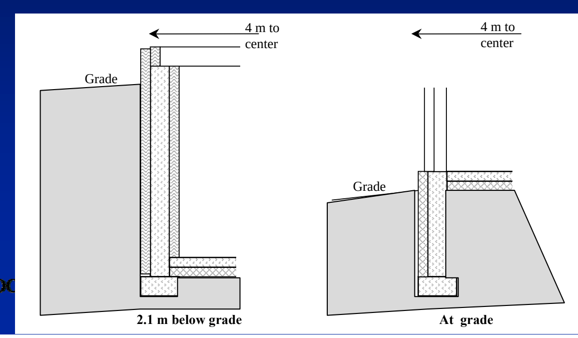


Two-Dimensional Dynamic

- Thermally Massive Systems
  - Energy
  - Surface condensation
- Blocon - Heat2 v4.0 (USD320 www.blocon.se)
- Physibel- Sectra (www.physiblel.be)

Case Study: Sub-slab insulation below Radiant Heating

Question: Does the use of radiant floor heating change the normal rules of thumb regarding sub-slab insulation?
Approach: Dynamic 2- Heat flow model

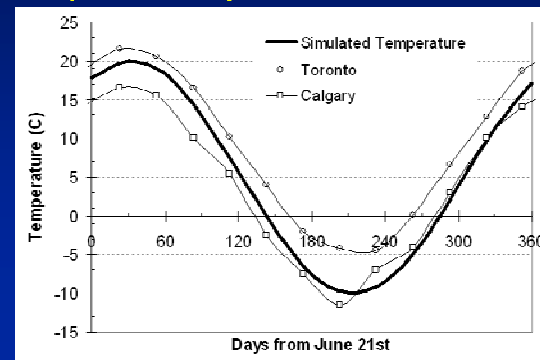


Case study

- Uses Heat2
- range of soil types and conductivity
- Apply heat in each tube
- Control upward flux to be the same in both

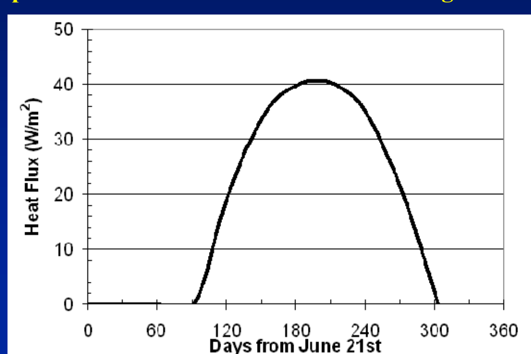
Boundary Conditions

- High thermal lag allows large time steps to be practical
- Created synthetic but representative “climate” file



Radiant Floor Heat Input

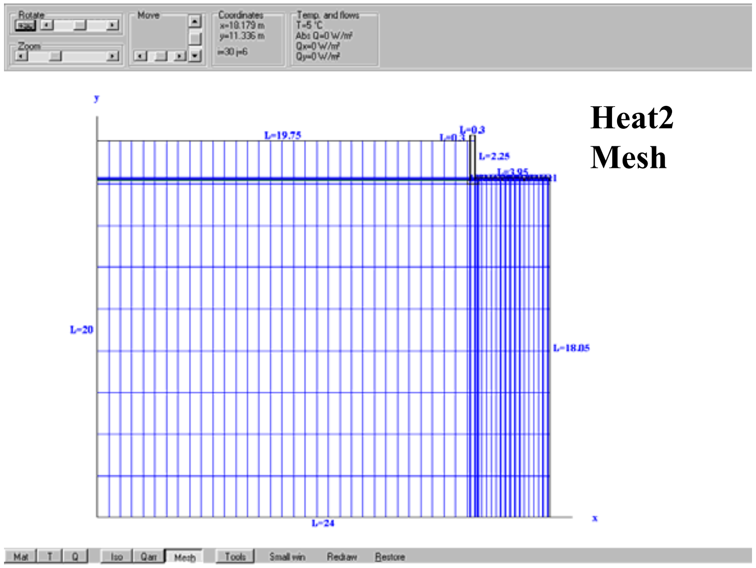
- Based radiant tubes heat output on weekly average outdoor temperature to balance conductive/air leakage losses

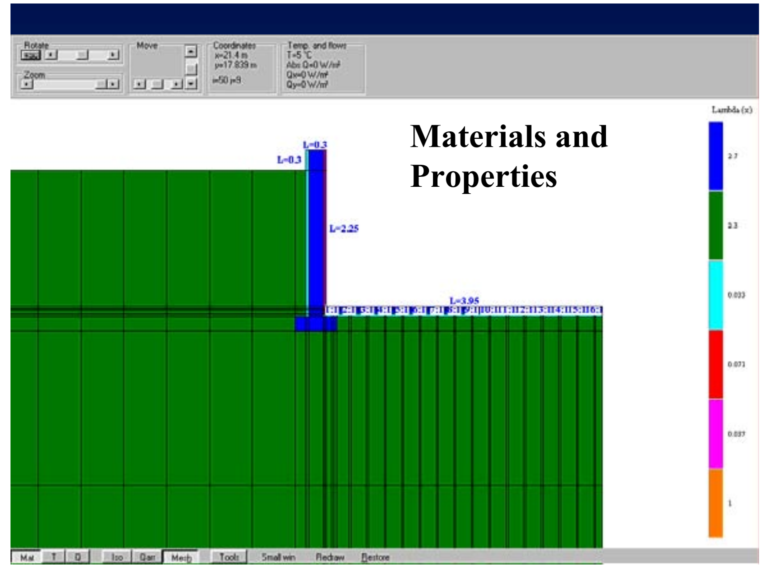


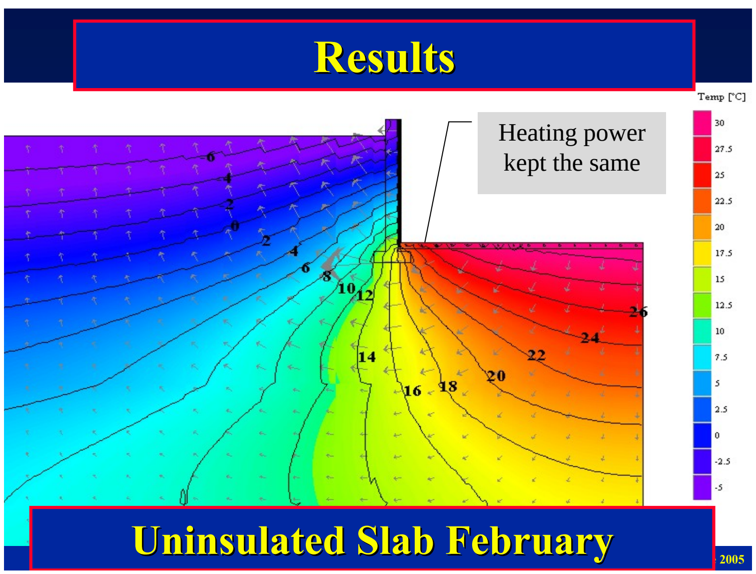
Material Properties

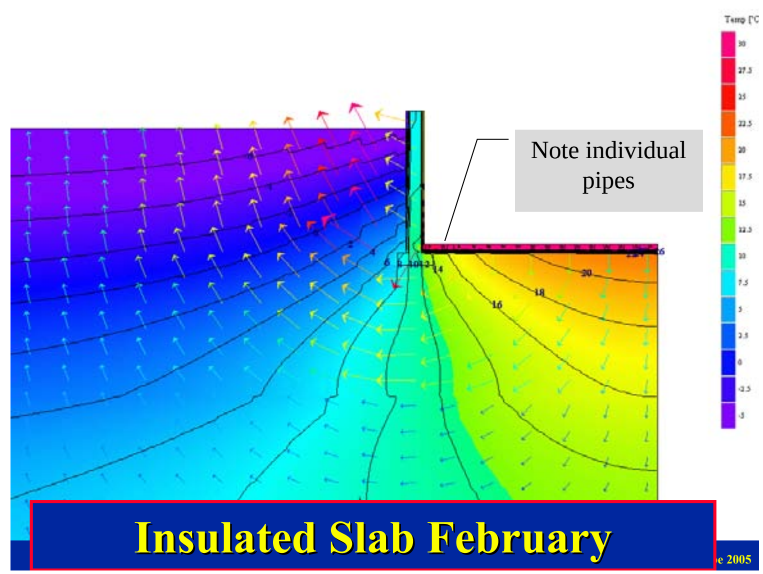
- Soil properties are both poorly known and important to the results
- Hence – parametric study

Soil Description	Conductivity (W/mK)	Heat Capacity (MJ/m^3 K)
Dry Sandy Loam	0.70	1.50
Moist Clay	1.50	1.65
Wet Sand	2.30	1.80

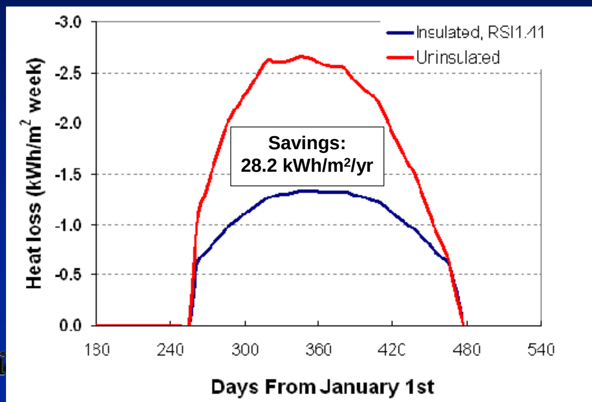

Heat2
Mesh
L=19.75
L=20
L=24
L=18.05
L=2.25
L=3.95
L=0.3


Materials and
Properties
L=0.3
L=2.25
L=3.95


Results
Heating power
kept the same
Temp [°C]
Uninsulated Slab February


Note individual
pipes
Insulated Slab February

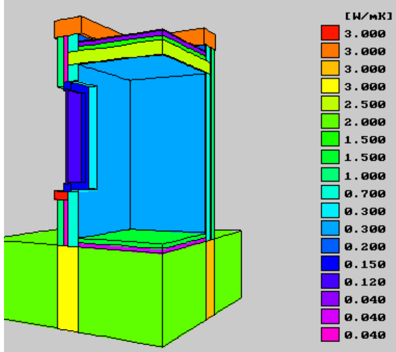
Heat loss compared

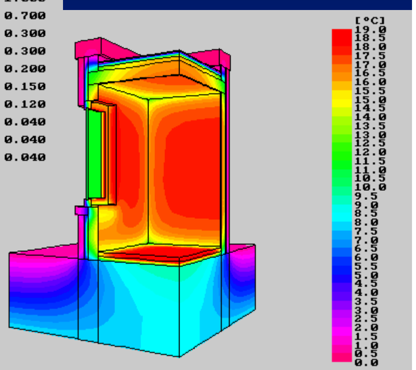


Three-Dimensional Heat Flow

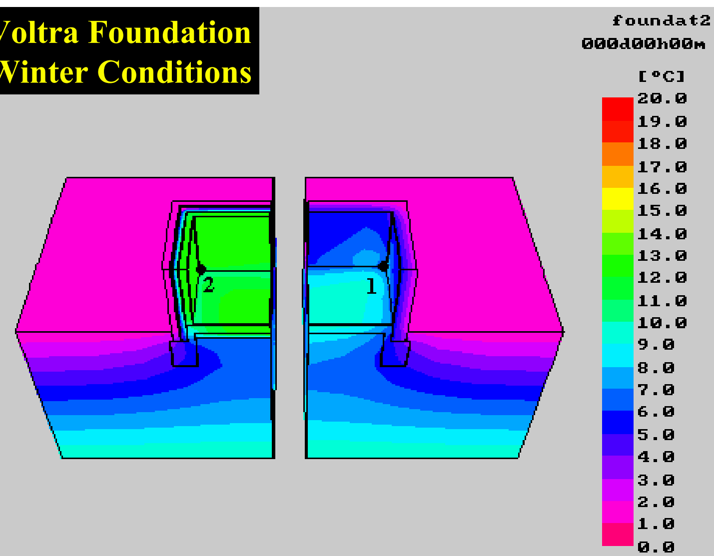
- Steady-state: systems with complex shapes
  - point thermal bridges, ties, connections
- Dynamic: thermally massive complex
  - as above but thermal mass, fires, foundations
- Rarely require this detail -- easier to be clever
- Commercial Tools
  - Physibel Voltra (dynamic) Trisco (static)
  - Blocon Heat3 (both USD520)
  - Heat 7.2 (ORNL - not really commercial)

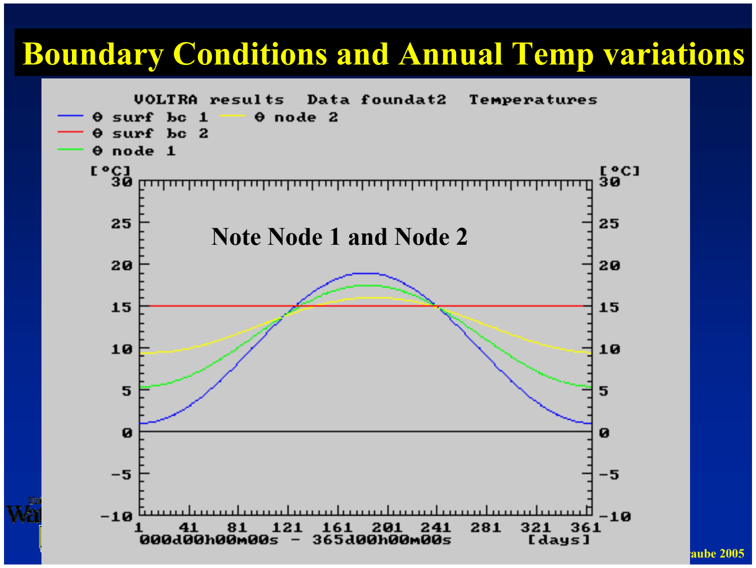
Trisco - 3D steady state

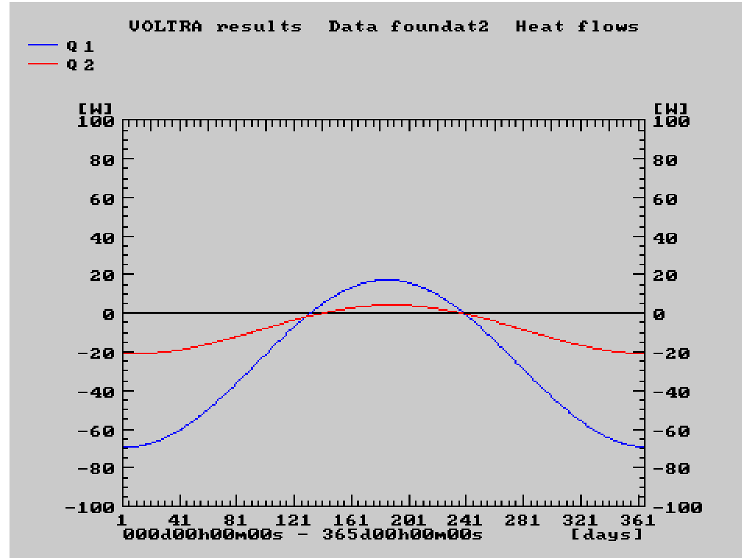




Voltra Foundation Winter Conditions




Boundary Conditions and Annual Temp variations
VOLTRA results Data foundat2 Temperatures
θ surf bc 1
θ node 2
θ surf bc 2
θ node 1
[°C]
Note Node 1 and Node 2
30
25
20
15
10
5
0
-5
-10
1 41 81 121 161 201 241 281 321 361
000d00h00m00s - 365d00h00m00s
[days]


VOLTRA results Data foundat2 Heat flows
Q 1
Q 2
[W]
100
80
60
40
20
0
-20
-40
-60
-80
-100
1 41 81 121 161 201 241 281 321 361
000d00h00m00s - 365d00h00m00s
[days]