NRC·CNRC

Institute for Research in Construction

Hygrothermal Performance of Cool Reflective and Conventional Roofs

Hamed Saber

On Behalf of

Mike Swinton, Peter Kalinger and Ralph Paroli

September 8th, 2010

NRCA's 2011 International Roofing Conference, Washington

OUTLINE

- Introduction
- Objectives
- Roof System Configurations
- Hygrothermal Modeling
- Environmental Conditions
  - Outdoor
  - Indoor
- Results
- Summary

Introduction

hygrothermal **IRC-C**OMSOL →**hygIRC-C**

- ✓ recently developed
- ✓ solves 2D and 3D time dependent **HAM** transport equations.
- ✓ benchmarked against existing hygIRC-2D and experiments
- ✓ New features:
  - ➢ CFD capability to model drainage cavities, airspaces, cracks, etc… as well as aerodynamics on buildings
  - ➢ Heat transfer by radiation through airspace enclosures of building envelope (e.g. reflective insulations)
  - ➢ Runoff due to wind driven rain on facades

Introduction (cont.)

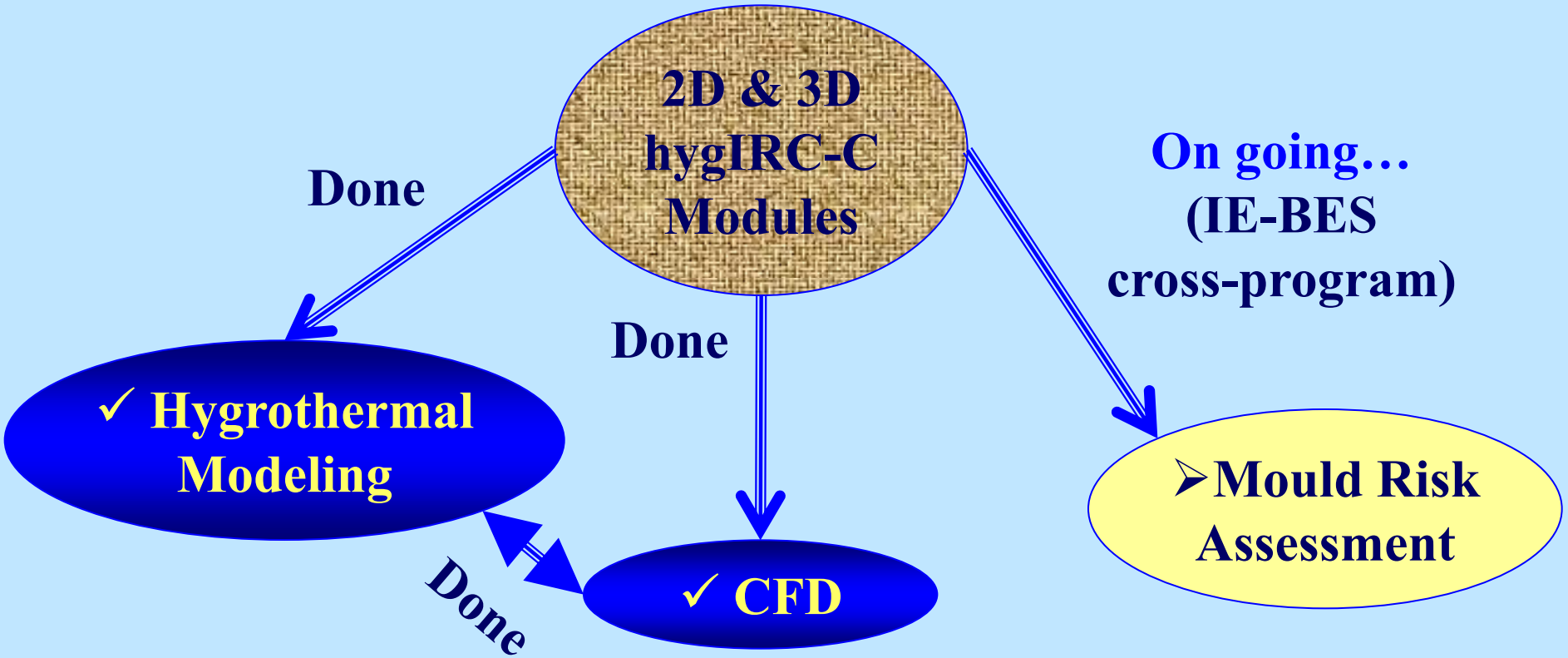
- **Examples of Numerical Simulations Conducted Using 2D and 3D hygIRC-C:**
  1. hygIRC-C vs hygIRC
  2. Wetting and Drying of Cladding Systems
  3. Moisture Assessment of Cladding Systems
  4. Drying of Ventilated Wall Cavities
  5. Evaluating Wall Energy Rating (WER)
  6. Thermal Performance of Skylight Devices (ASHRAE –RP1415)
  7. Foundation Wall Systems with Furred-Airspace Assembly
  8. Insulated Concrete Foam (ICF) Wall systems
  9. **Hygrothermal Performance of Roofing Systems**
  10. Aerodynamics on Buildings
  11. Thermal Performance of EIFS Walls with Drainage Cavities
  12. Hygrothermal Performance of Samples Used in Current Mould Experiments
  13. Phase Change Materials (PCMs)

Introduction (cont.)

On going…

- A new module for predicting the risk for mould growth will be implemented in hygIRC-C.
- hygIRC-C will be used to predict the performance of the whole building.

Introduction (cont.)



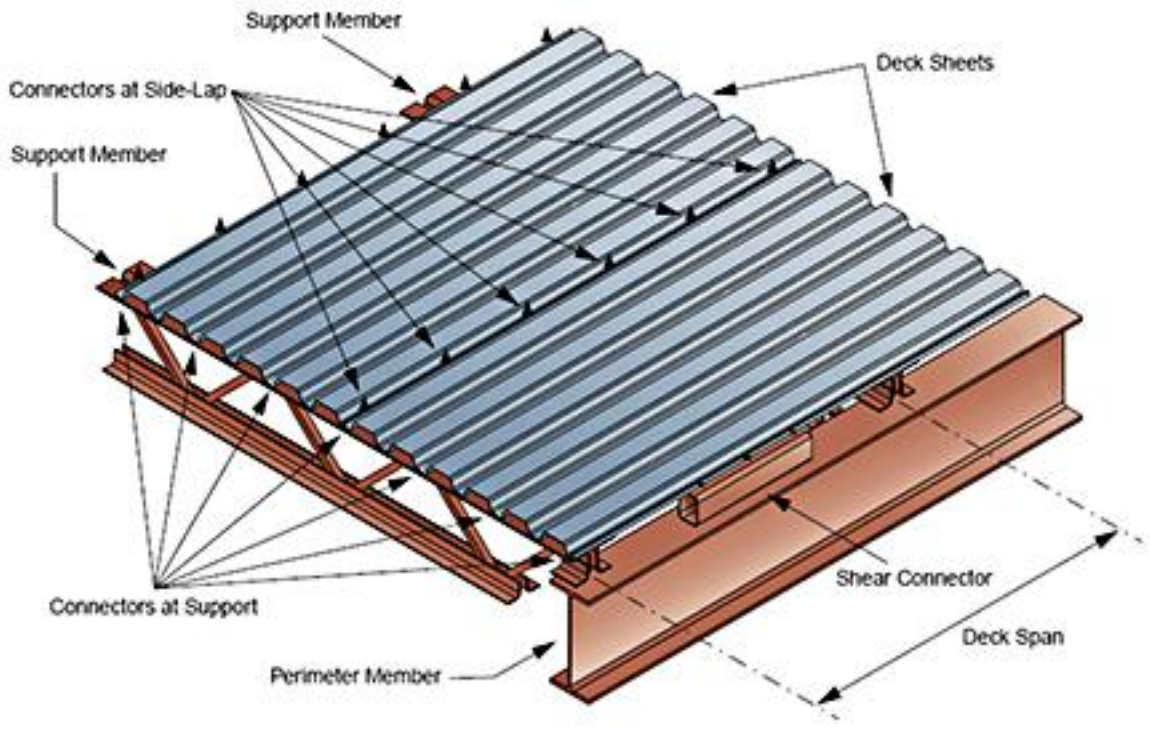
Objectives

- Use hygIRC-C to investigate the hygrothermal performance of reflective and non-reflective roof systems subjected to North American climates
- Investigate the effect of indoor conditions on the roof performance
- Compare the hygrothermal performance (moisture and energy loss/gain) of reflective and non-reflective roof systems

Roof System Configurations

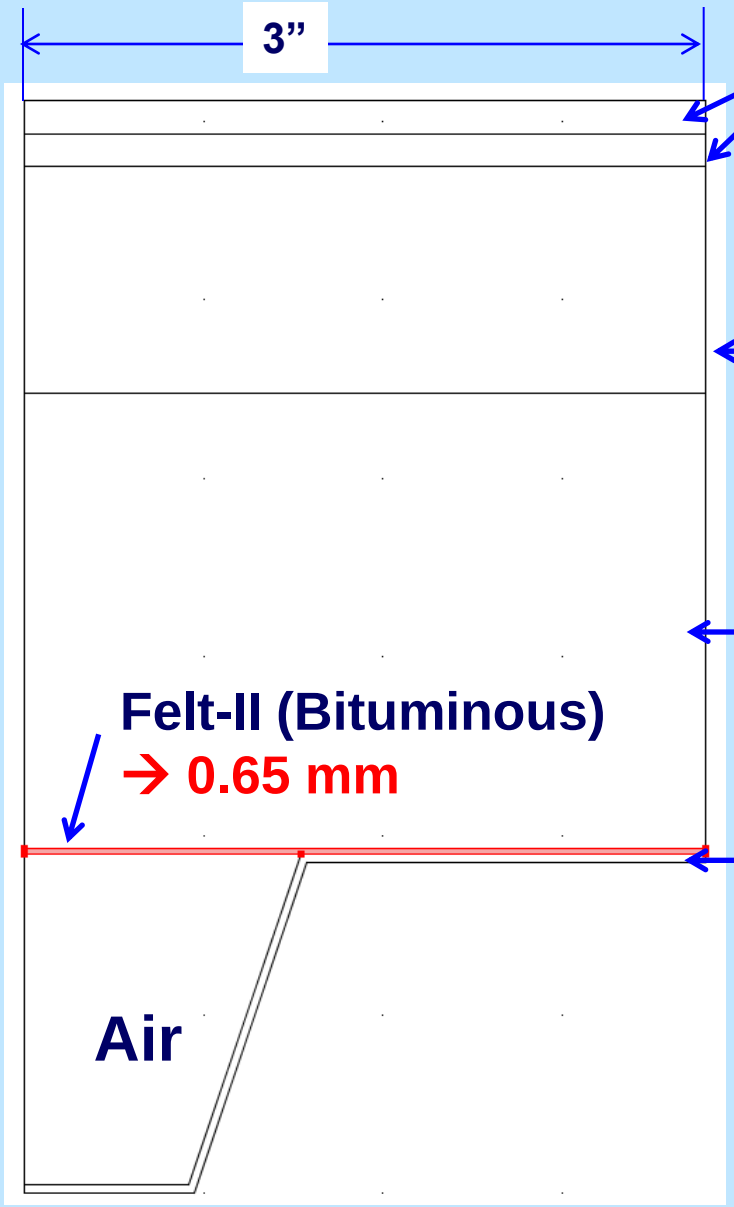
MOD-BIT

Steel Deck (From Canam)



P-3615 & P-3606 → P-3615

Roof Configurations (cont.)



Cap Sheet with Base Sheet

0.30” → 7.34 mm total thickness

92 PERD Torch applied asphalt based membrane

1” Fibreboard

54 ASHRAE Fibreboard

Insulation:

Polyisocyanurate → 2” (50 mm)

72 ASHRAE Polyisocyanurate Insulation

Felt-II (Bituminous)

→ 0.65 mm

Steel Deck (P-3615)

Steel deck vapor permeance
3.3 m (5 US perms)

Hygrothermal Modeling

Assumptions:

All material layers are in good contact

Initial Conditions:

→ Moisture Content in all layers corresponding to 50% RH and T = 10°C

Indoor Conditions:

→ ASHRAE

→ EN15026

Outdoor Conditions:

Weather data of North America

→ NRC weather database

Time for simulation:

→ 5 years

→ Up to 11 years

Solar short-wave absorption coeff.:

→ 0.2 (white roof)

→ 0.88 (black roof)

Long-wave emissivity:

→ 0.9 for black & white roofs

Material Properties:

→ NRC material database

Environmental Conditions

Outdoor Conditions: North American Climates

Canadian cities (NBCC):

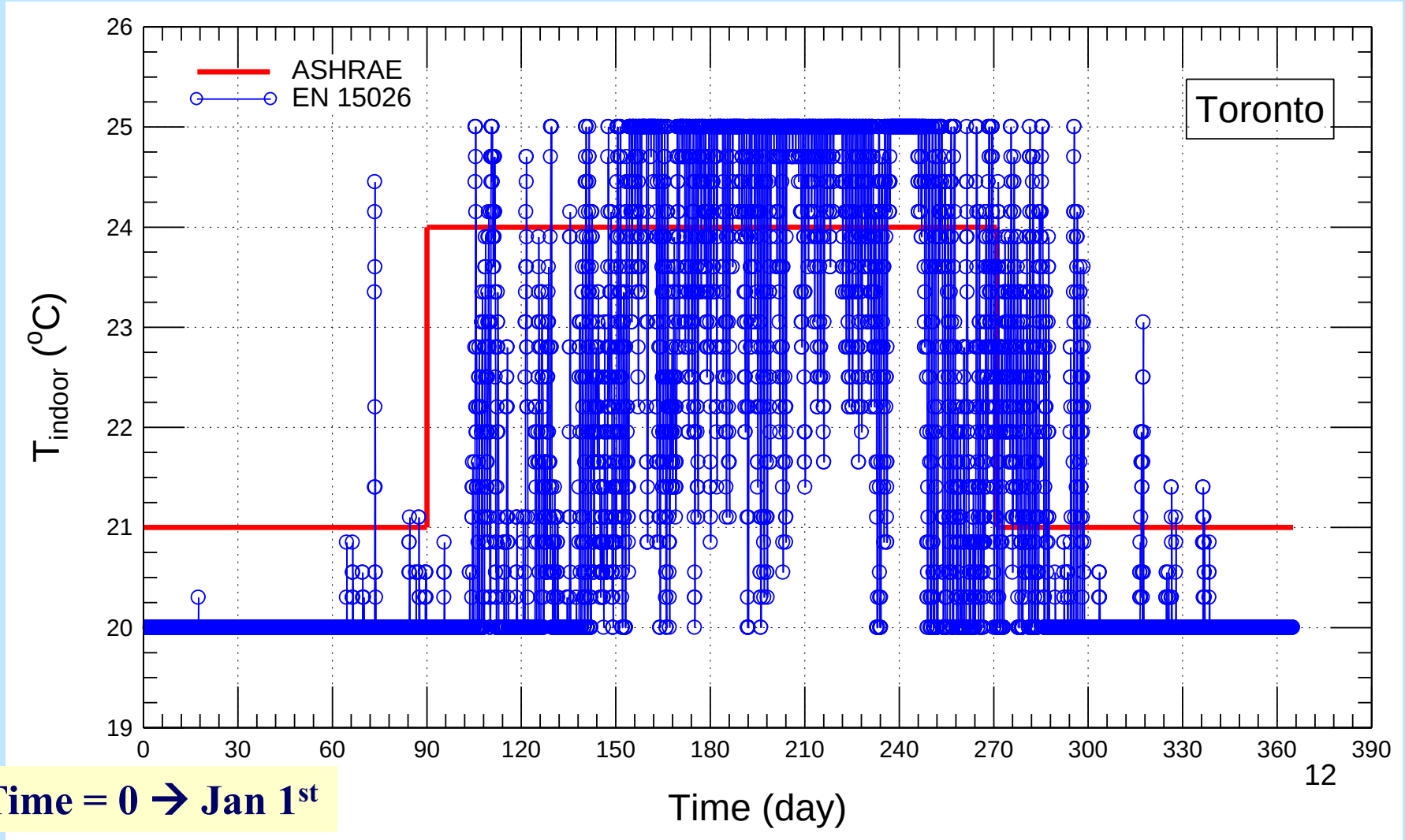
- ✓ Toronto (HDD = 3650)
- ✓ Montreal (HHD = 4200)
- ✓ St. John's (HDD = 4800)
- ✓ Saskatoon (HDD = 5950)

US cities:

- ✓ Seattle (HDD = 2564)
- ✓ Wilmington (HDD = 1349)
- ✓ Phoenix (HDD = 578)

Environmental Conditions (cont.)

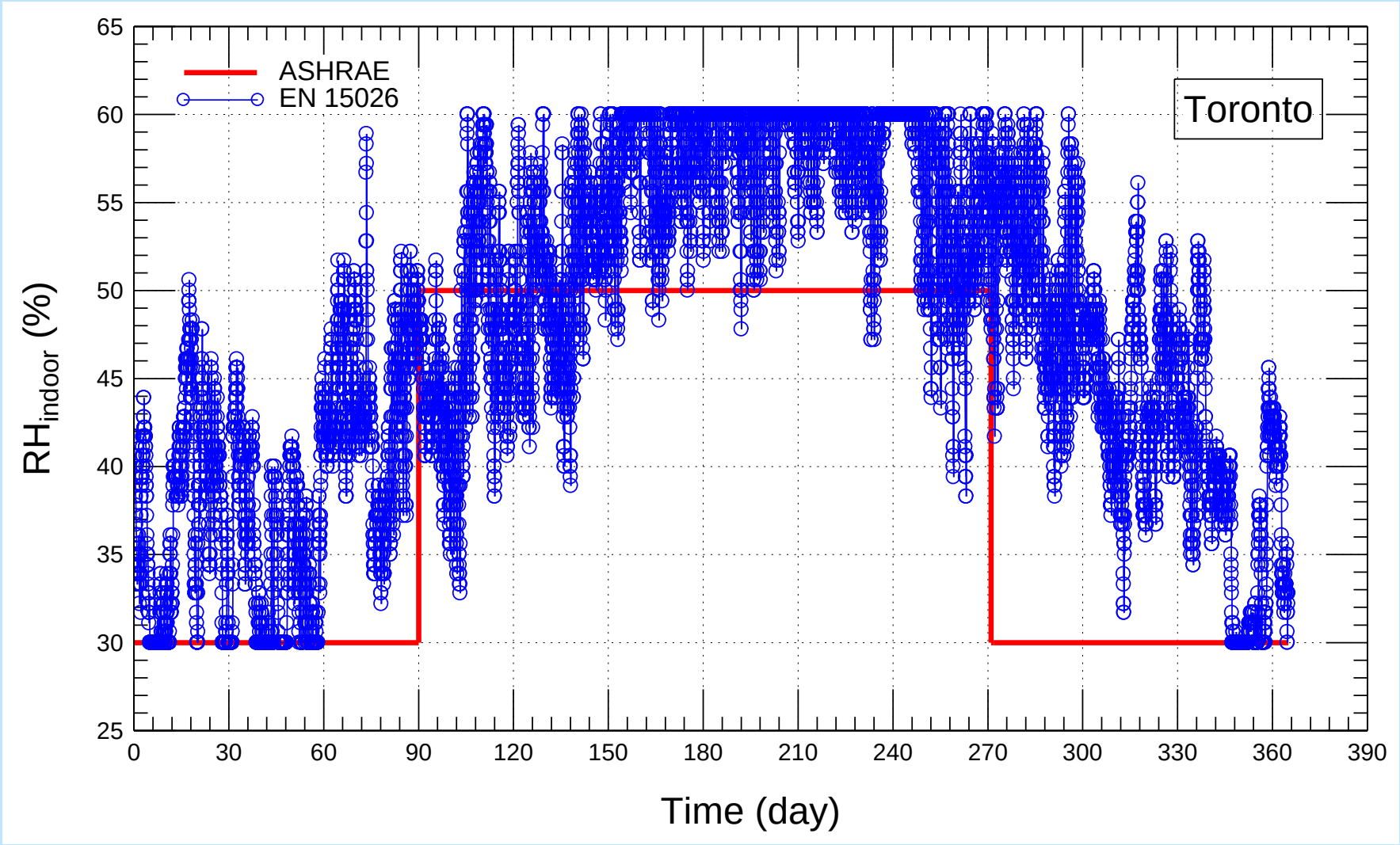
Indoor Conditions: ASHRAE vs EN15026



Time = 0 → Jan 1st

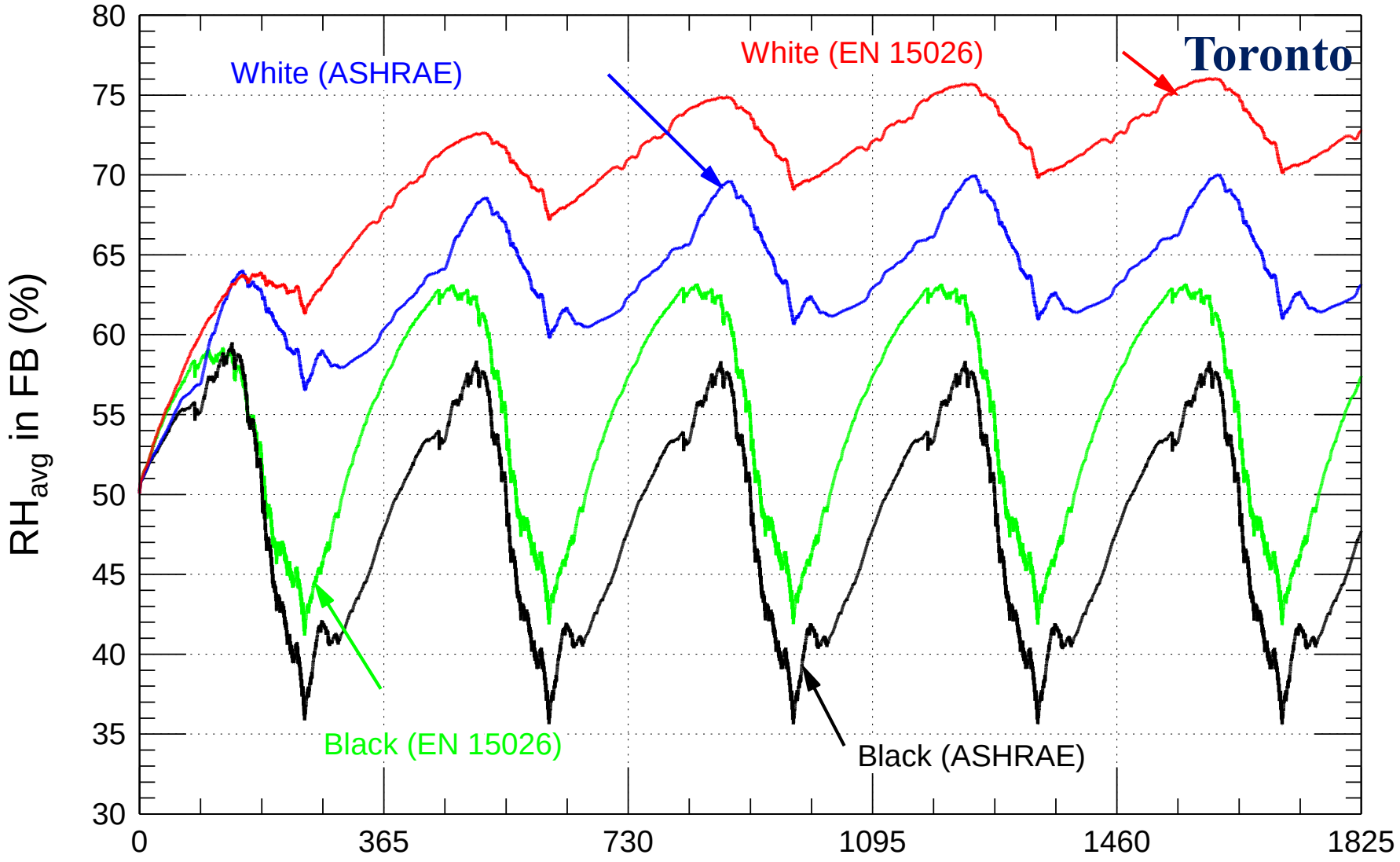
Environmental Conditions (cont.)

Indoor Conditions: ASHRAE vs EN15026



Time = 0 → Jan 1st

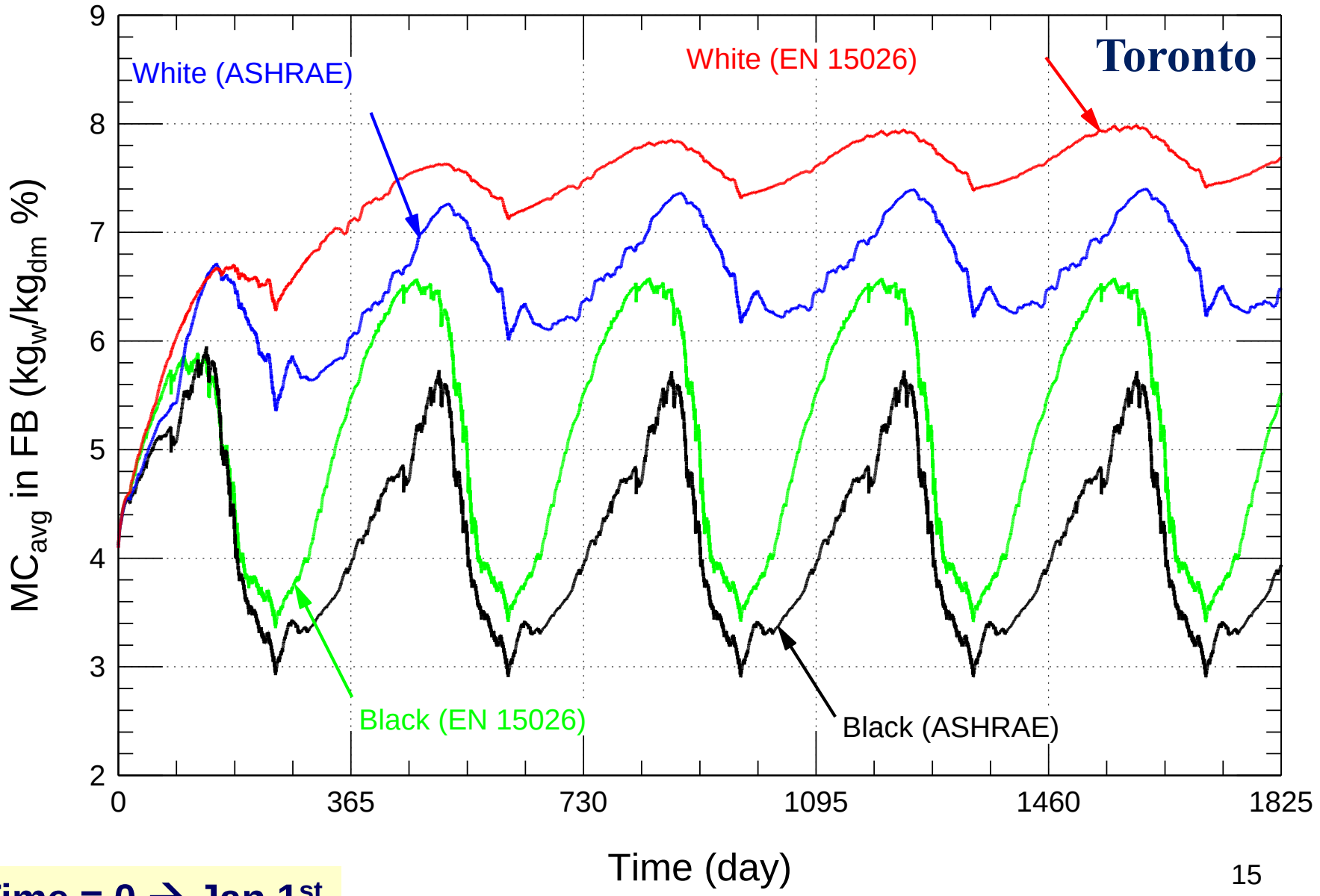
ASHRAE vs EN15026 Results (cont.)



Time = 0 → Jan 1st

ASHRAE vs EN15026

Results (cont.)



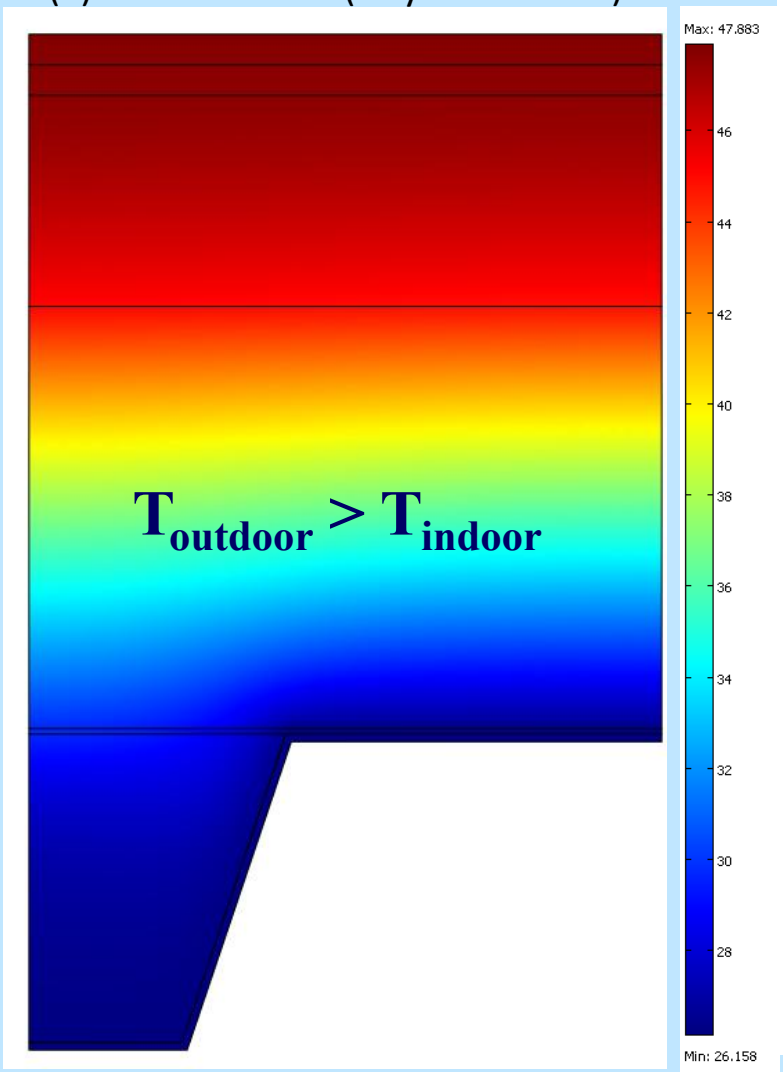
Time = 0 → Jan 1st

Toronto, EN15026 (black roof)

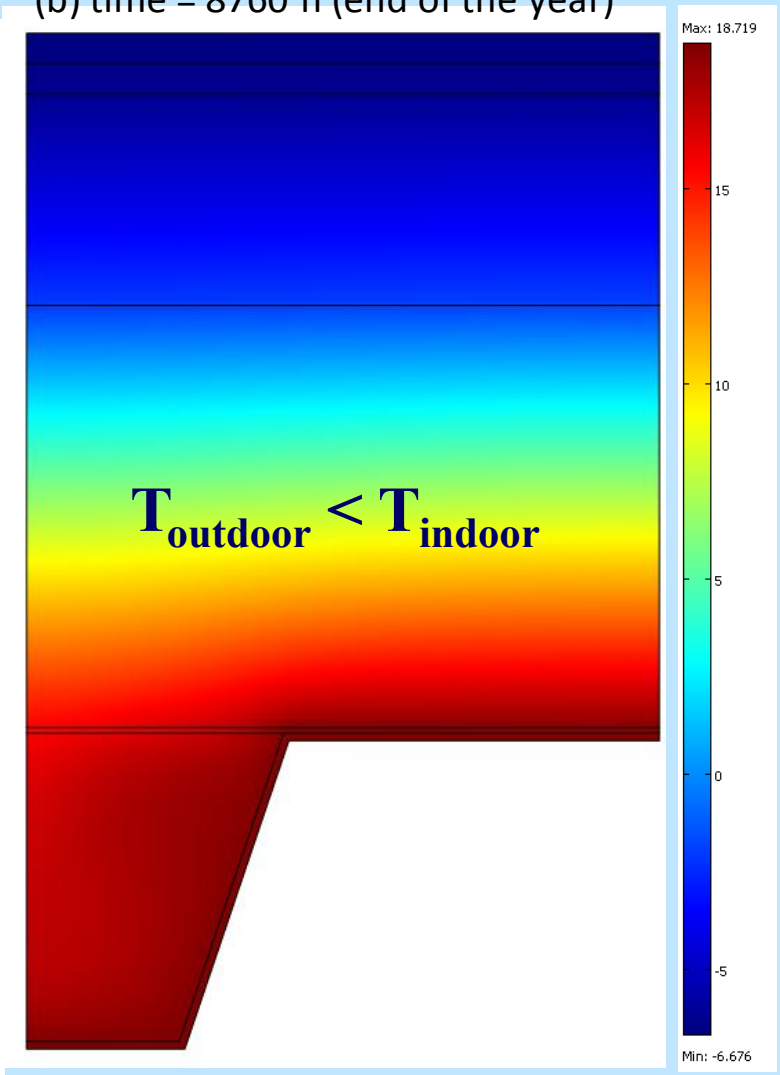
Results

Temperature contours (in ^{o}C)

(a) time = 4356 h (July 1st at noon)

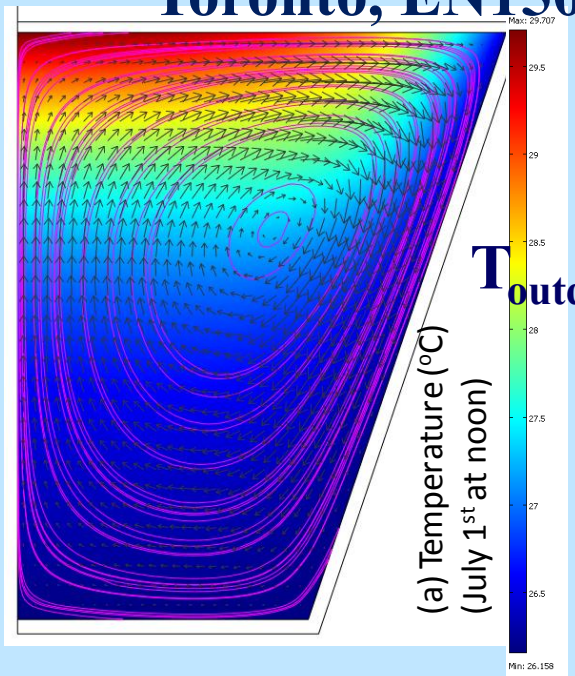


(b) time = 8760 h (end of the year)



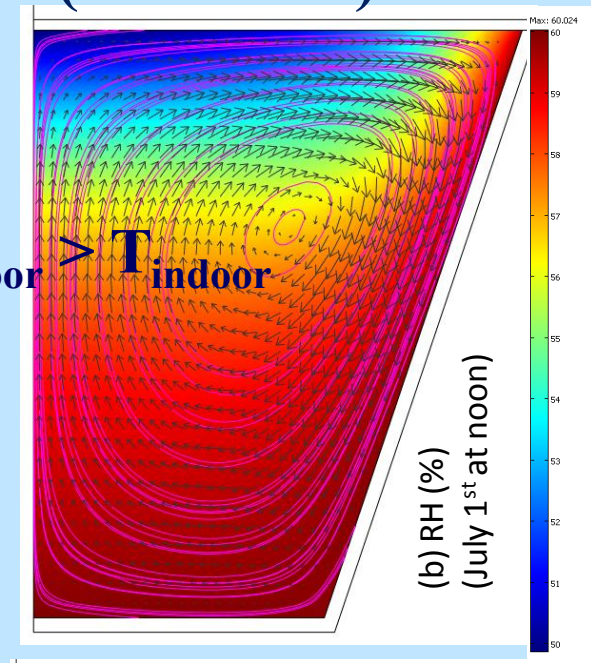
Toronto, EN15026 (black roof)

Results (cont.)

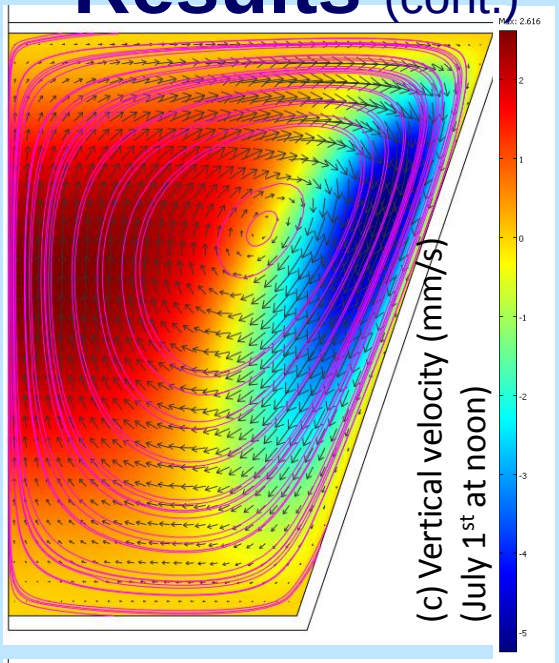


(a) Temperature (°C)
(July 1st at noon)

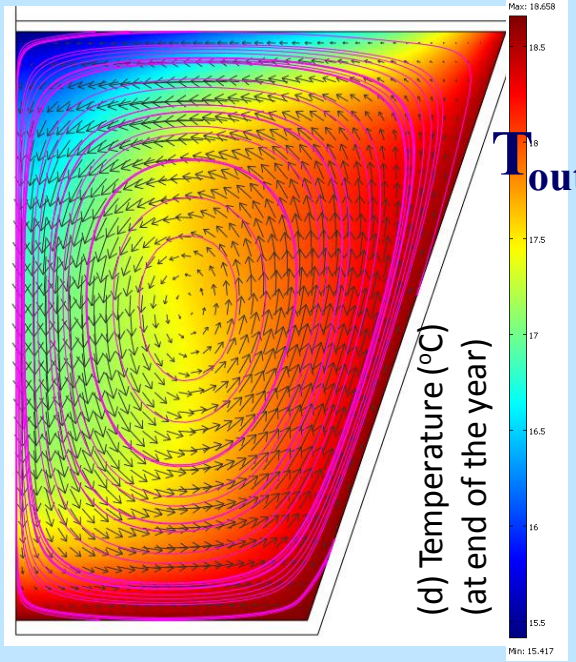
$T_{outdoor} > T_{indoor}$



(b) RH (%)
(July 1st at noon)

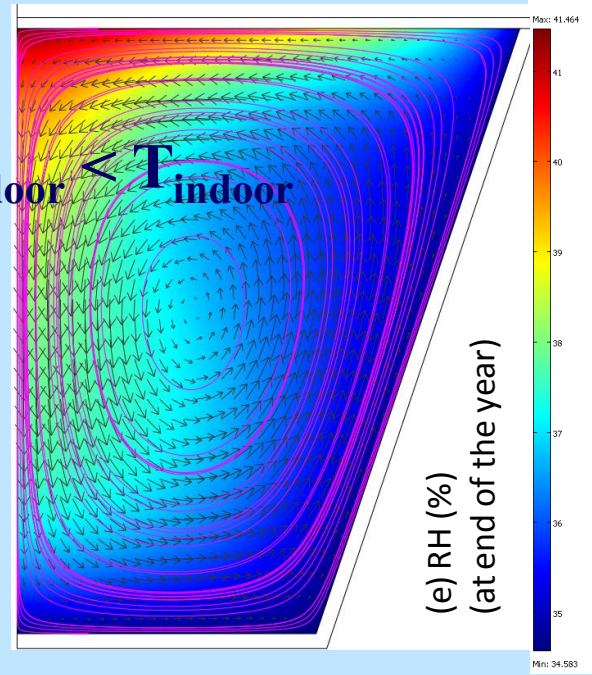


(c) Vertical velocity (mm/s)
(July 1st at noon)

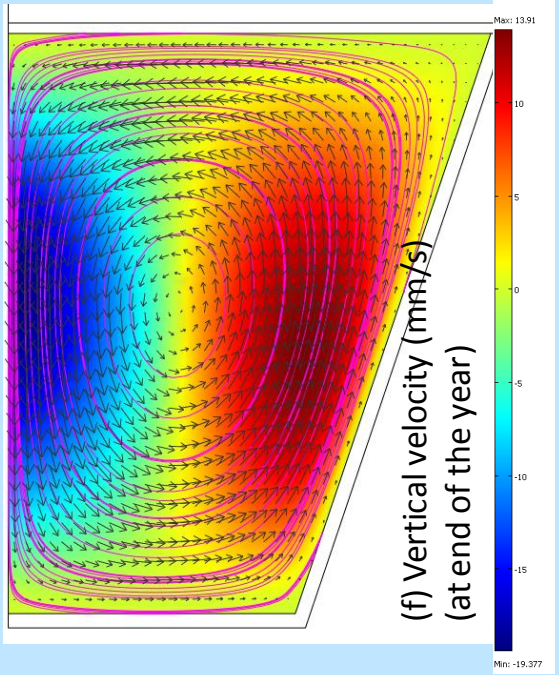


(d) Temperature (°C)
(at end of the year)

$T_{outdoor} < T_{indoor}$



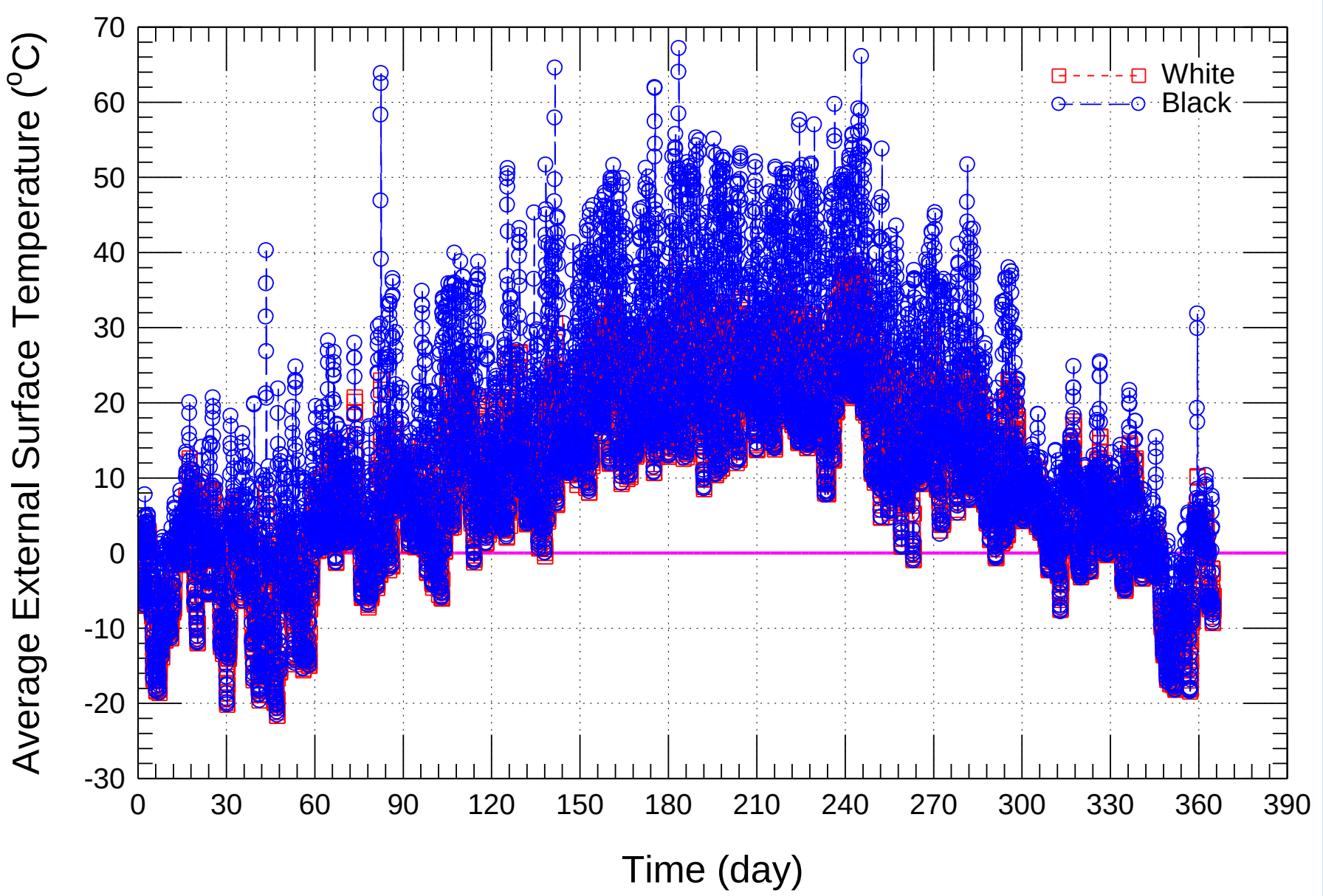
(e) RH (%)
(at end of the year)



(f) Vertical velocity (mm/s)
(at end of the year)

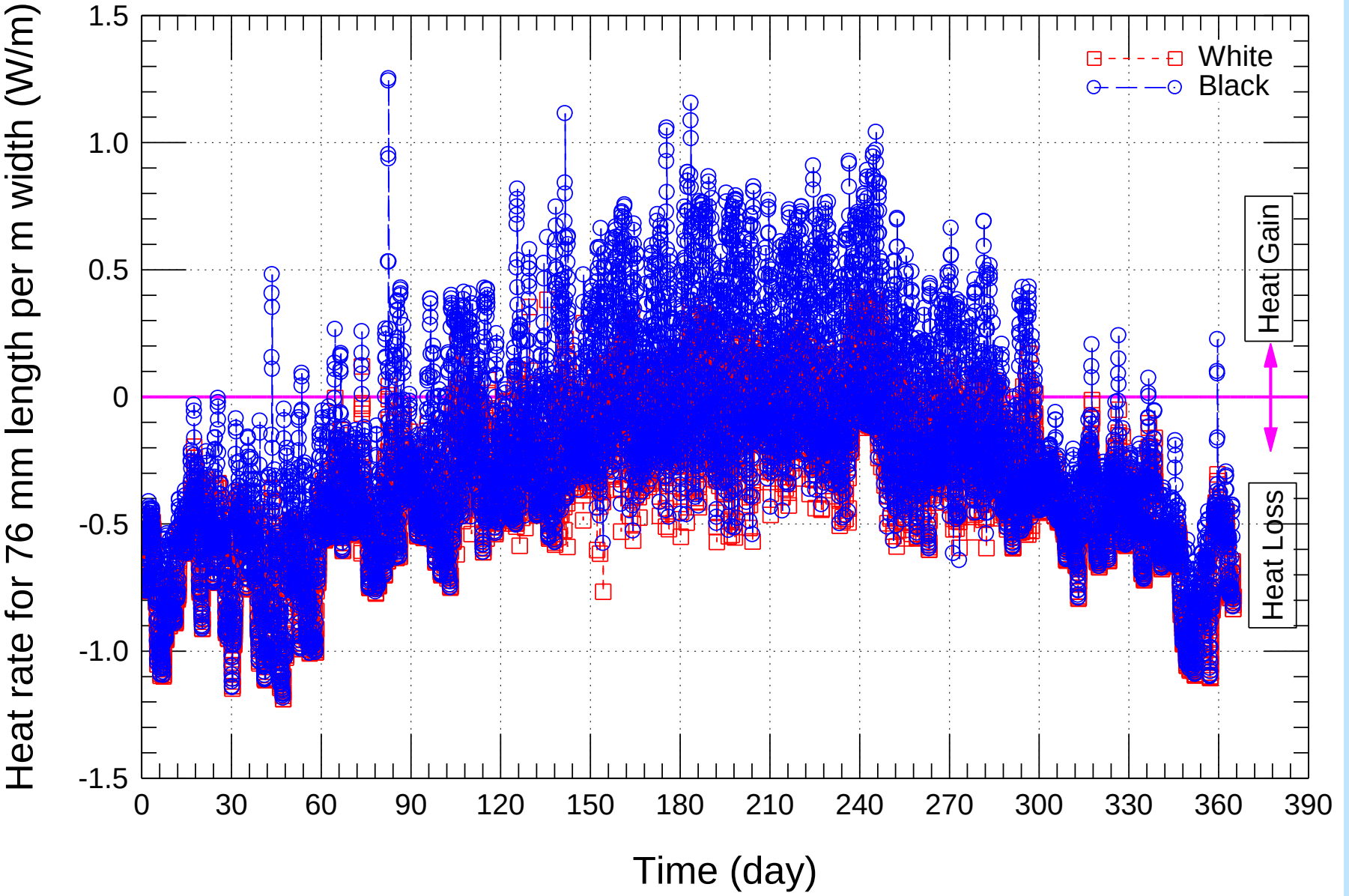
Toronto, EN15026

Results (cont.)



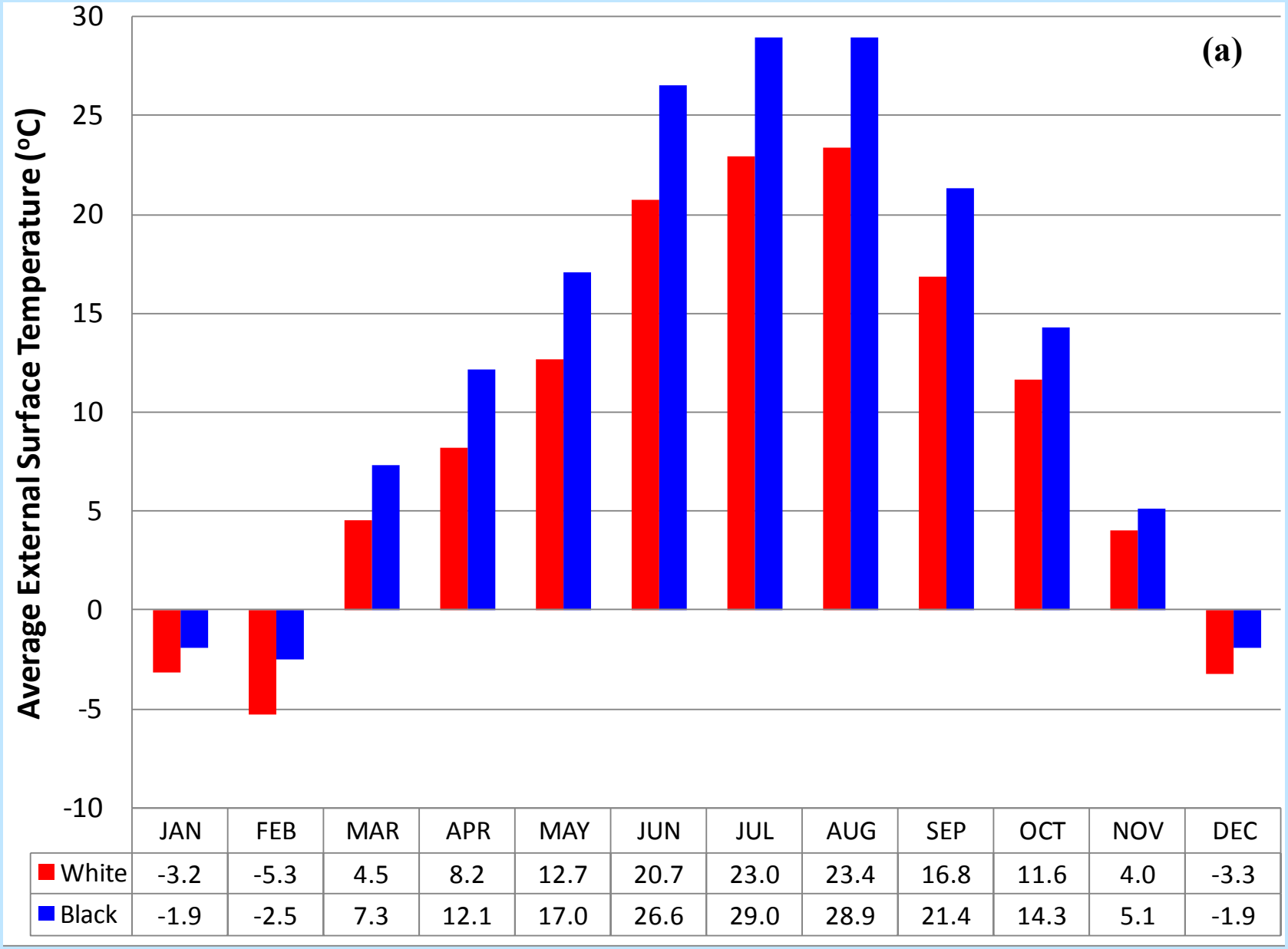
Toronto, EN15026

Results (cont.)



Toronto, EN15026

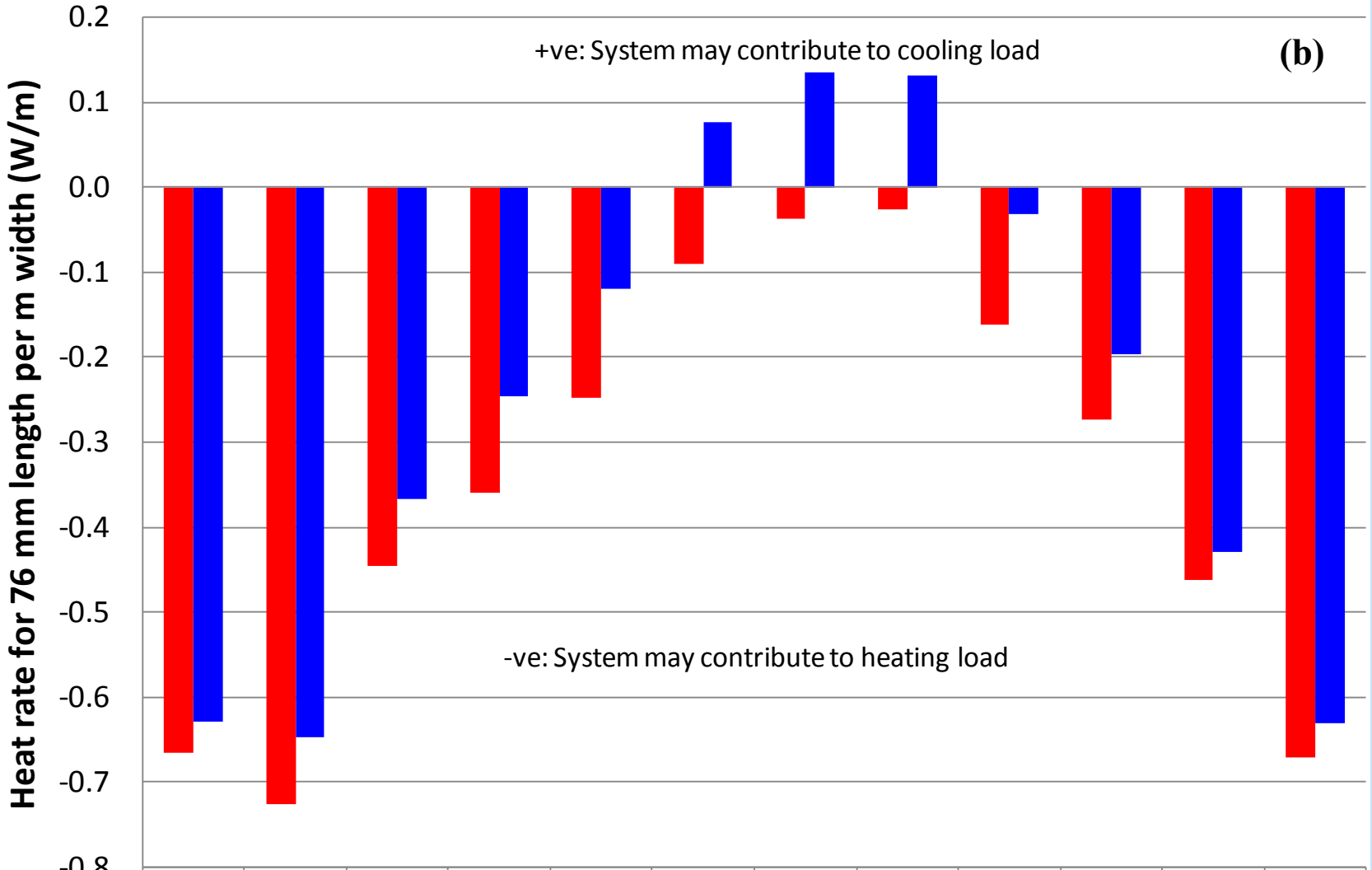
Results (cont.)



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
White	-3.2	-5.3	4.5	8.2	12.7	20.7	23.0	23.4	16.8	11.6	4.0	-3.3
Black	-1.9	-2.5	7.3	12.1	17.0	26.6	29.0	28.9	21.4	14.3	5.1	-1.9

Toronto, EN15026

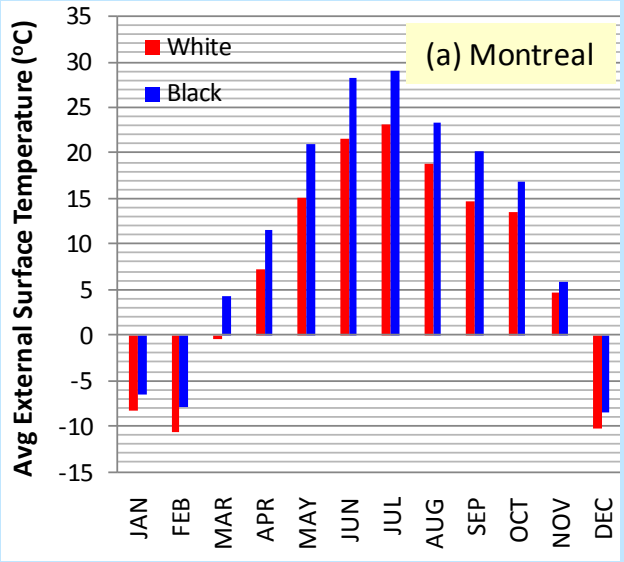
Results (cont.)

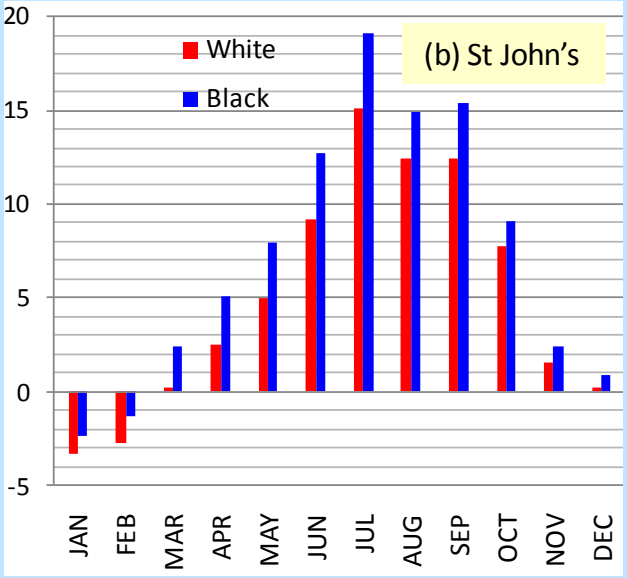


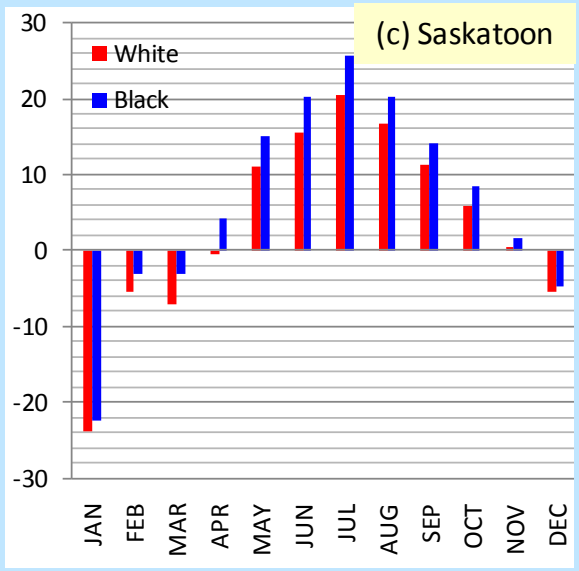
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
White	-0.67	-0.73	-0.45	-0.36	-0.25	-0.09	-0.04	-0.03	-0.16	-0.27	-0.46	-0.67
Black	-0.63	-0.65	-0.37	-0.25	-0.12	0.08	0.14	0.13	-0.03	-0.20	-0.43	-0.63

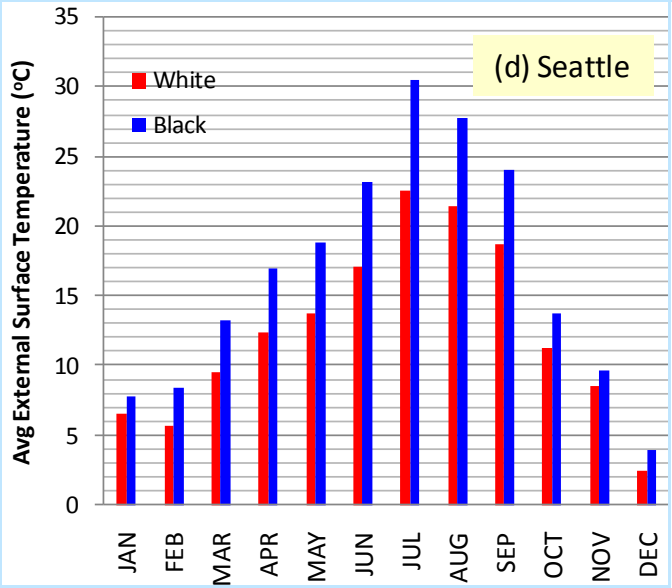
EN15026

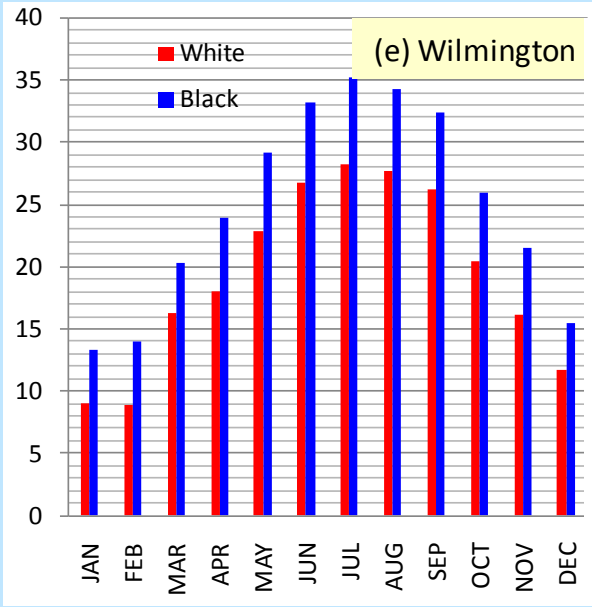
Results (cont.)

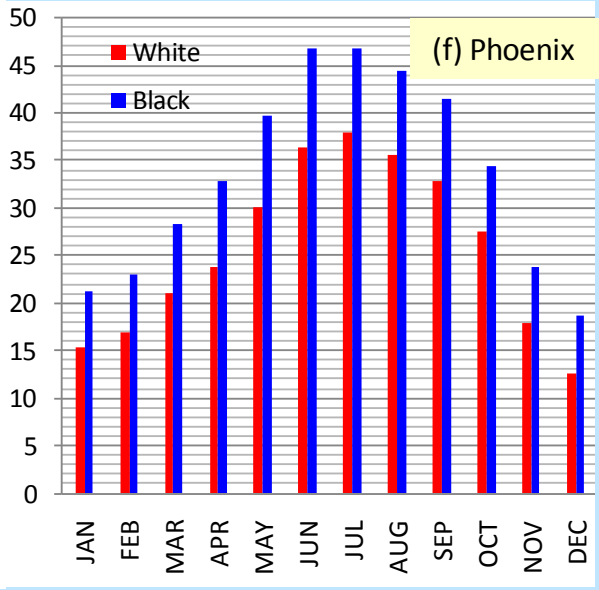












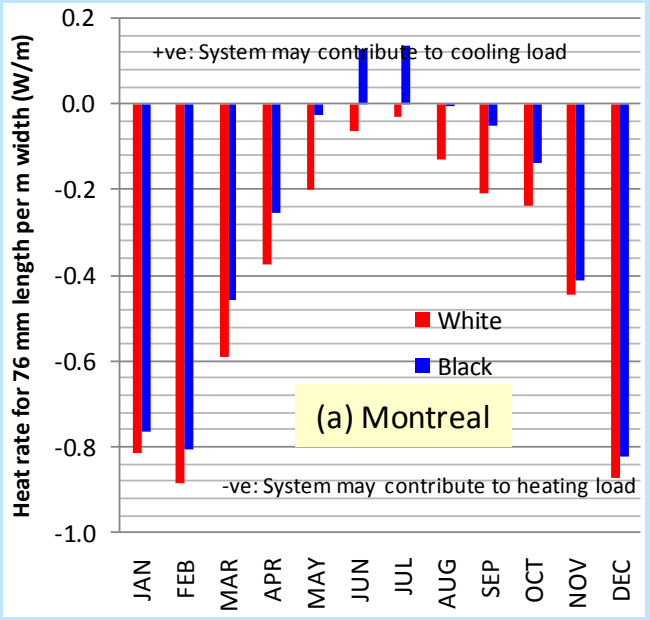
EN15026

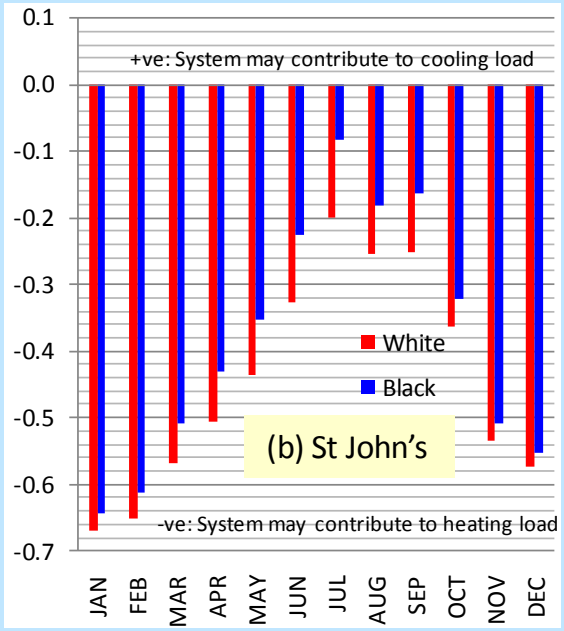
Results (cont.)

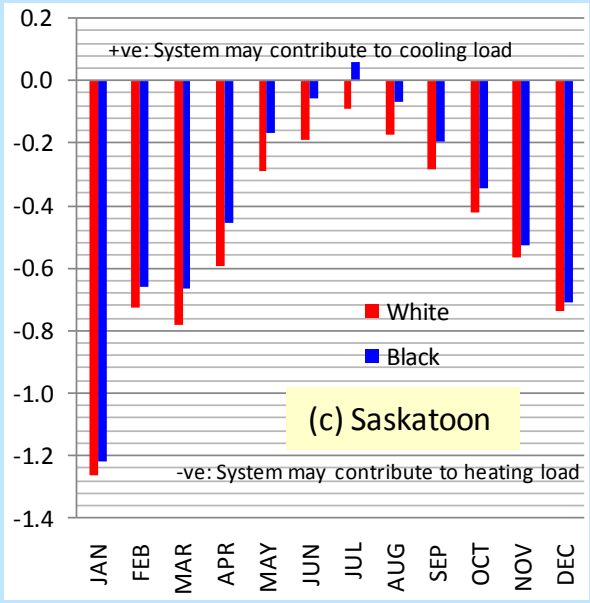
City	Maximum Surface Temperature (°C)				Minimum Surface Temperature (°C)			
	Hourly		Monthly Average		Hourly		Monthly Average	
	Black Roof	White Roof	Black Roof	White Roof	Black Roof	White Roof	Black Roof	White Roof
Toronto	67	39	29	23	-22	-22	-3	-5
Montreal	75	39	29	23	-29	-29	-9	-11
St John's	51	32	19	15	-15	-15	-2	-3
Saskatoon	65	39	26	20	-42	-42	-22	-24
Seattle	68	39	30	23	-10	-10	4	2
Wilmington	78	42	35	28	-8	-8	13	9
Phoenix	81	52	47	38	-3	-2	19	13

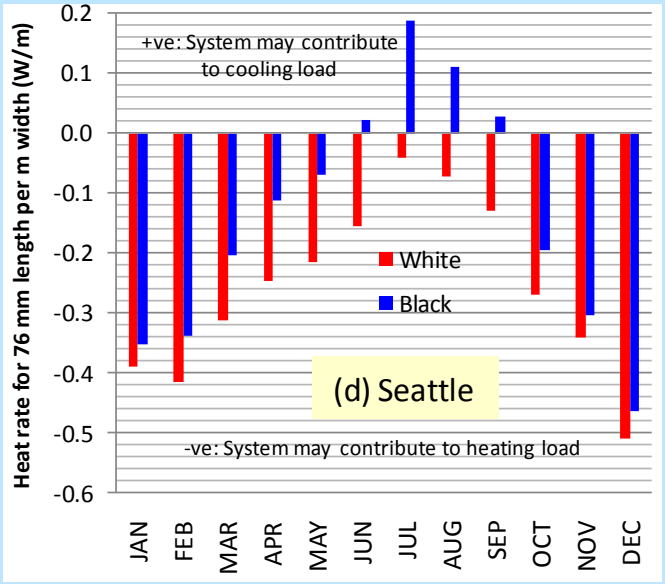
EN15026

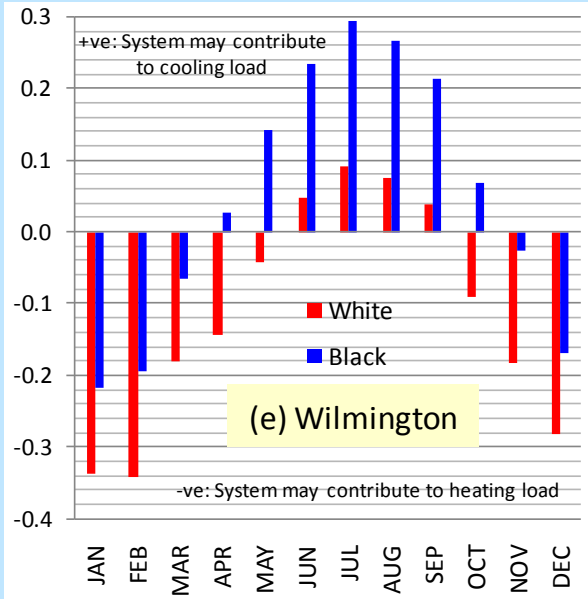
Results (cont.)

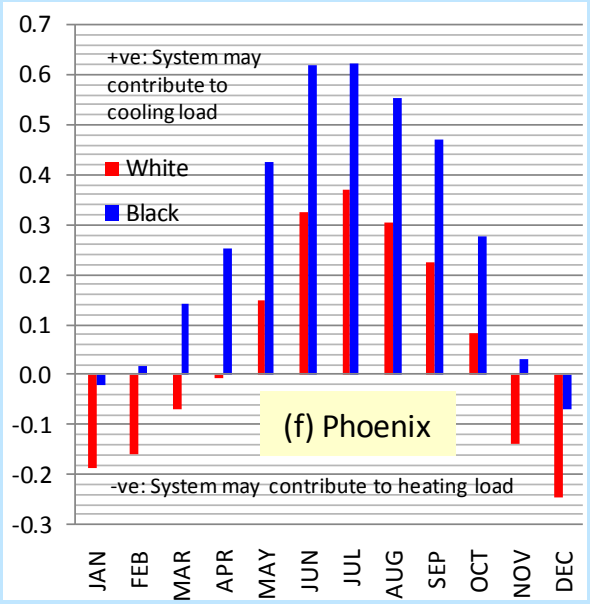












Results (cont.)

Cooling Load

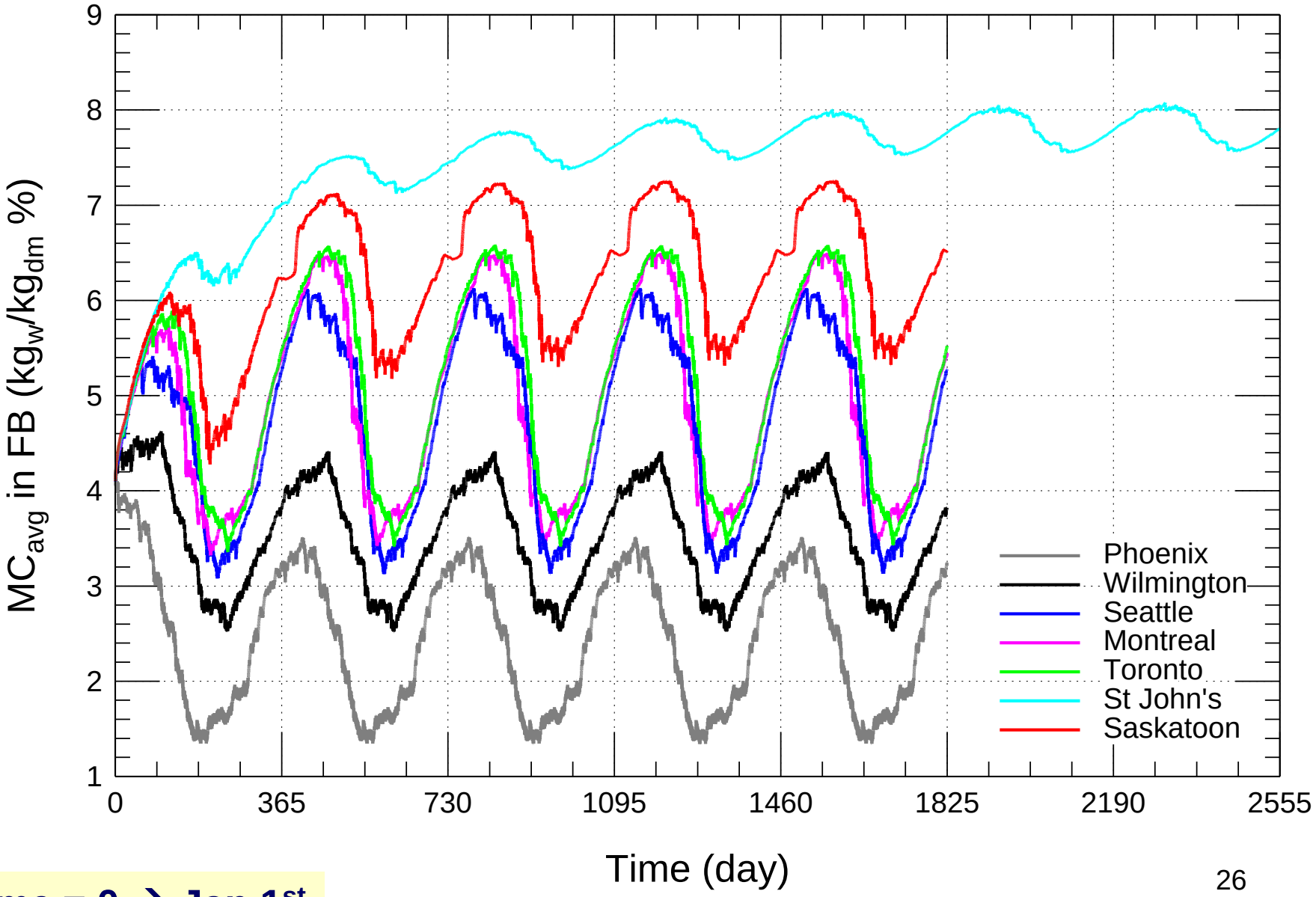
City	Yearly Accumulation Energy Gain (Wd/m)		Ratio
	Black Roof	White Roof	Black/White
Toronto	26.2	4.9	5.31
Montreal	25.7	3.8	6.71
St John's	6.8	0.5	13.02
Saskatoon	15.4	2.1	7.38
Seattle	30.7	4.5	6.85
Wilmington	61.8	14.9	4.15
Phoenix	126.5	53.2	2.38

Heating Load

City	Yearly Accumulation Energy Loss (Wd/m)		Ratio	
	Black Roof	White Roof	Black/White	
Toronto	-116.1	-131.9	0.88	12%
Montreal	-131.0	-151.3	0.87	13%
St John's	-146.3	-162.8	0.90	10%
Saskatoon	-168.1	-188.1	0.89	11%
Seattle	-82.2	-98.5	0.83	17%
Wilmington	-44.4	-55.9	0.79	21%
Phoenix	-25.7	-33.4	0.77	23%

Black Roof, EN15026

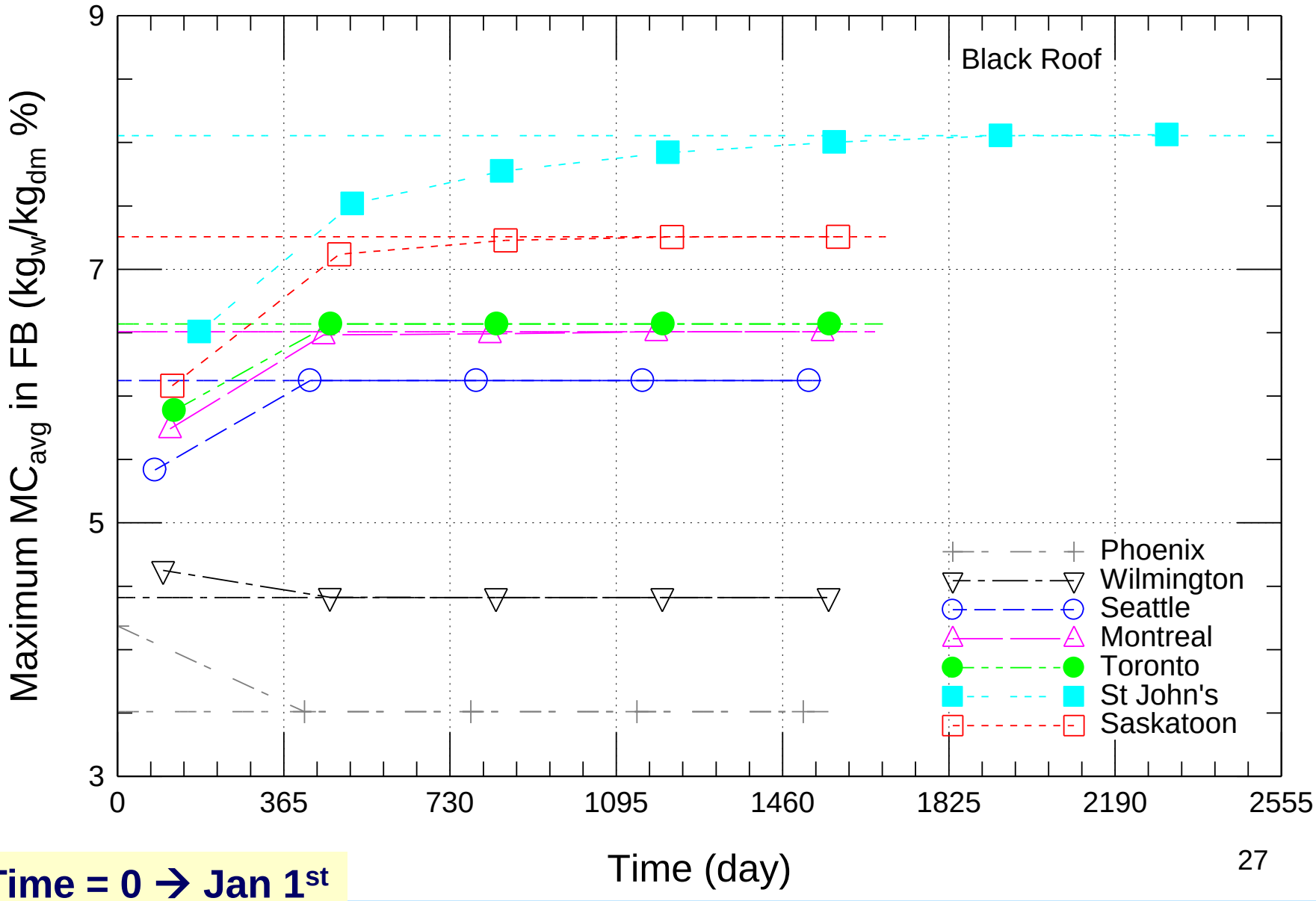
Results (cont.)



Time = 0 → Jan 1st

Black Roof, EN15026

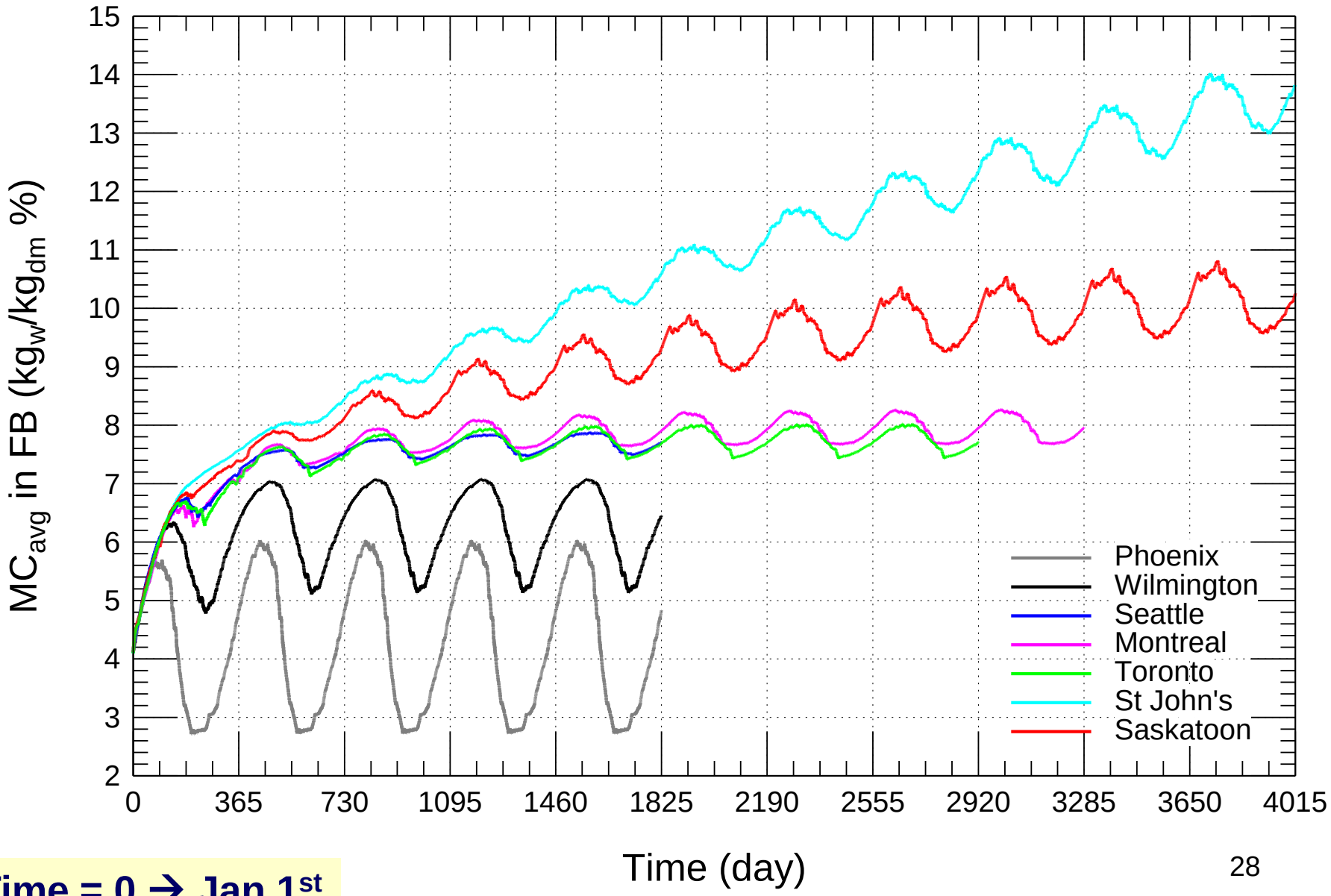
Results (cont.)



Time = 0 → Jan 1st

White Roof, EN15026

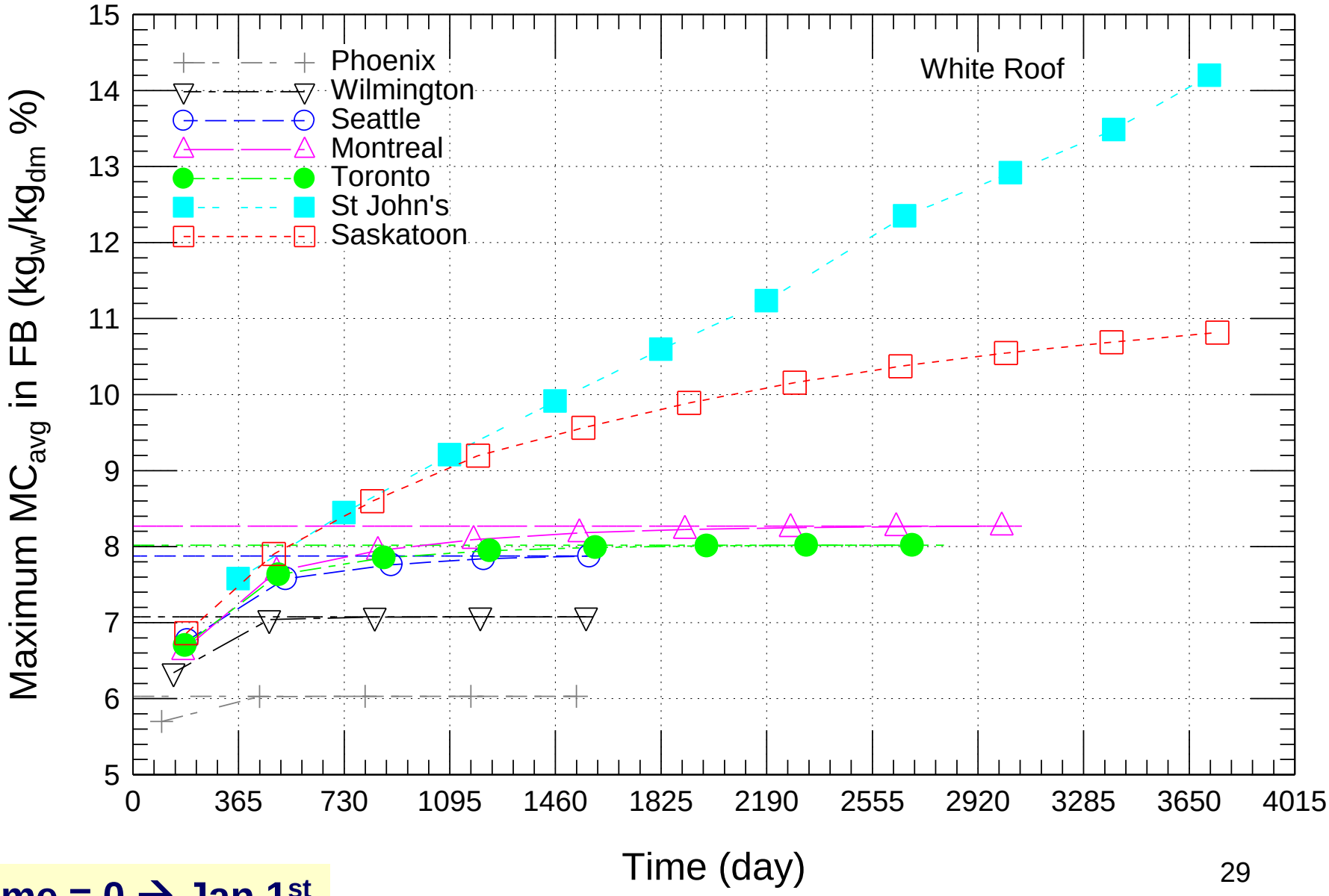
Results (cont.)



Time = 0 → Jan 1st

White Roof, EN15026

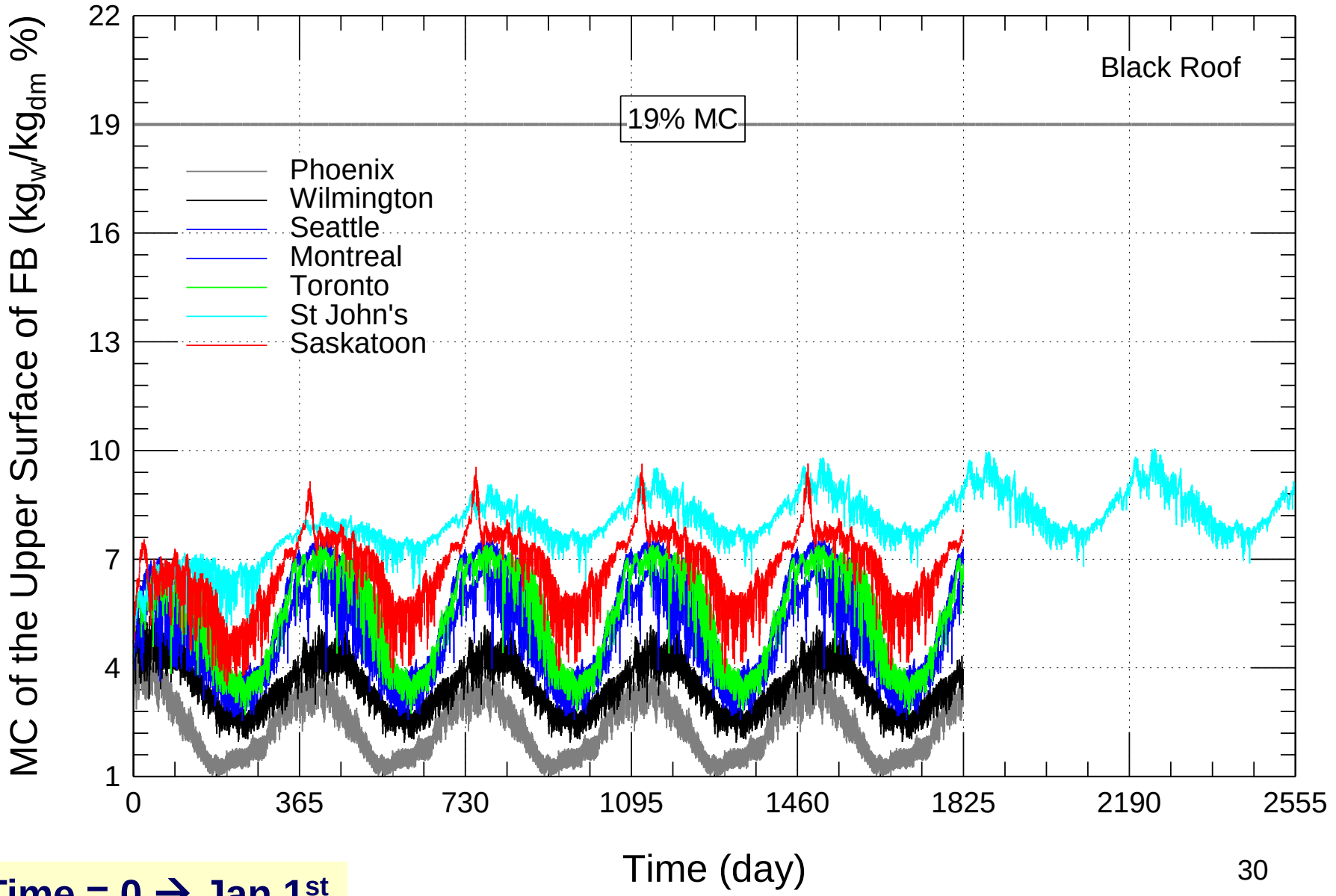
Results (cont.)



Time = 0 → Jan 1st

Black Roof, EN15026

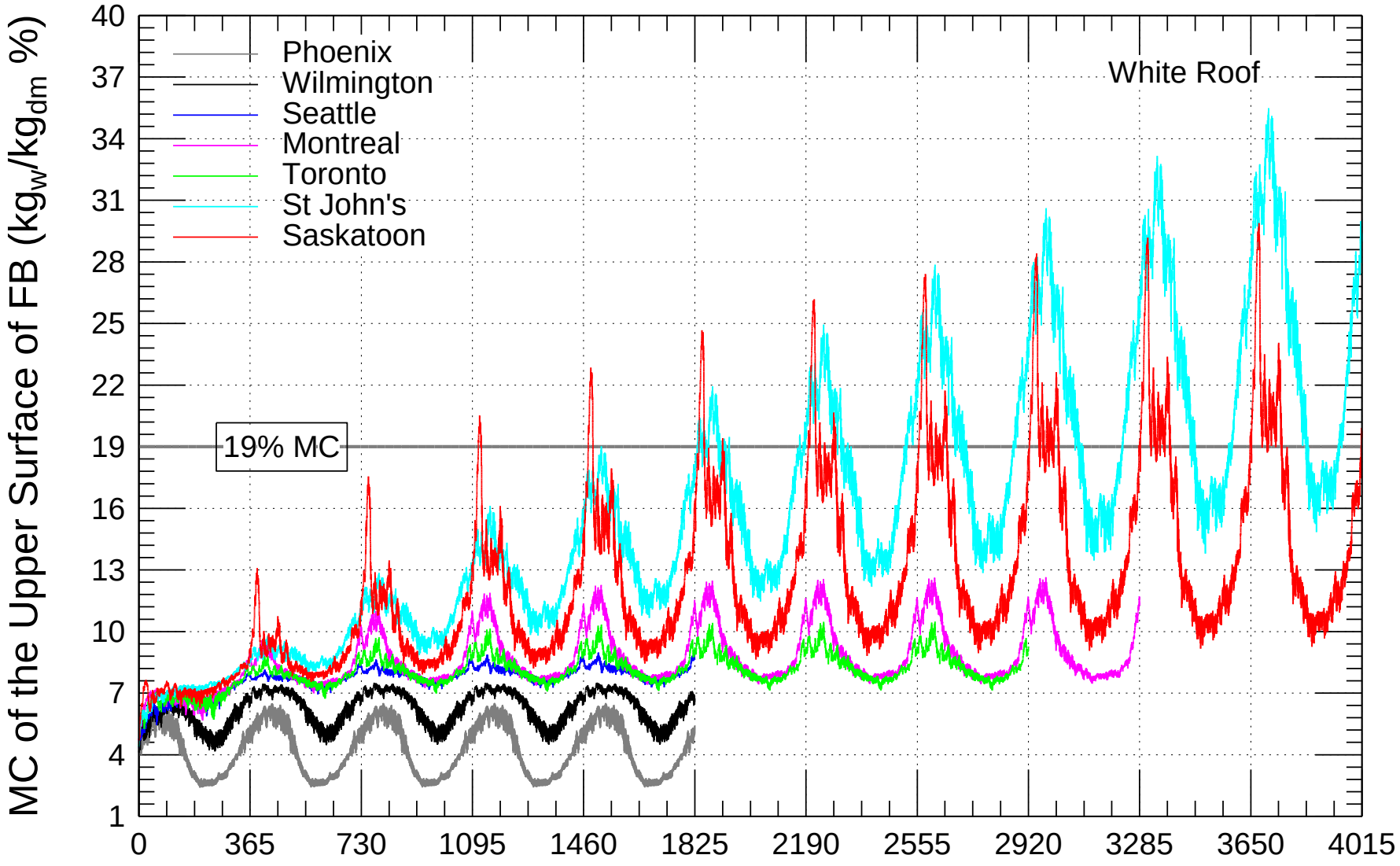
Results (cont.)



Time = 0 → Jan 1st

White Roof, EN15026

Results (cont.)



Time = 0 → Jan 1st

Summary

- **hygIRC-C was used to predict the hygrothermal performance of white and black MOD-BIT roofs subjected to different climates of North America**
- **The EN15026 indoor condition resulted in higher Moisture Content (MC) in the roof compared to ASHRAE indoor condition**
- **White roofs require less cooling load in summer compared to black roofs**
- **White roofs require more heating load in winter compared to black roofs**
- **White roofs run with low risk of moisture accumulation in all cities investigated in this paper except in St. John's and Saskatoon**

NRC CNRC

Institute for Research in Construction

Science at work for Canada

National Research Council Canada

Conseil national de recherches Canada

Canada