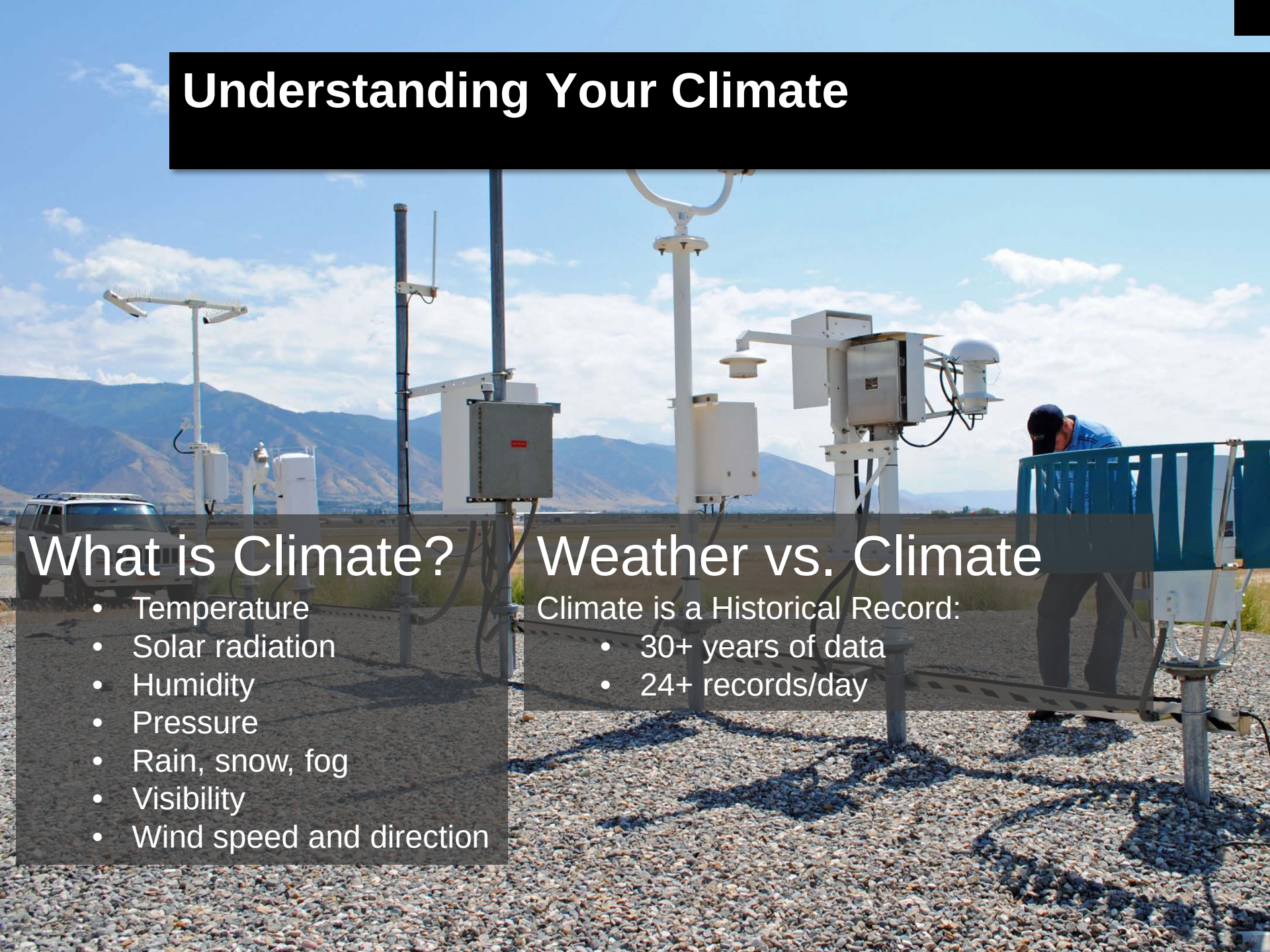
Accentuate the Positive: Climate Responsive Design

Understanding Your Climate



What is Climate?

- Temperature
- Solar radiation
- Humidity
- Pressure
- Rain, snow, fog
- Visibility
- Wind speed and direction

Weather vs. Climate

Climate is a Historical Record:

- 30+ years of data
- 24+ records/day

Climate – Other Considerations

- Climate is a 4-D problem (varies in space and time).
- Weather stations provide only a 1-D answer (time series at a single point in space).
- Surface-based measurements (e.g., airport weather stations) are influenced more strongly by the underlying surface than large-scale phenomena.
- Measurements at an airport do not necessarily reflect conditions in the surrounding urban area.
- Local factors that influence meteorology are always changing, as are global weather patterns.

Climate Consultant

http://www.energy-design-tools.aud.ucla.edu/

Climate Consultant 5 is a free tool available from the above address.

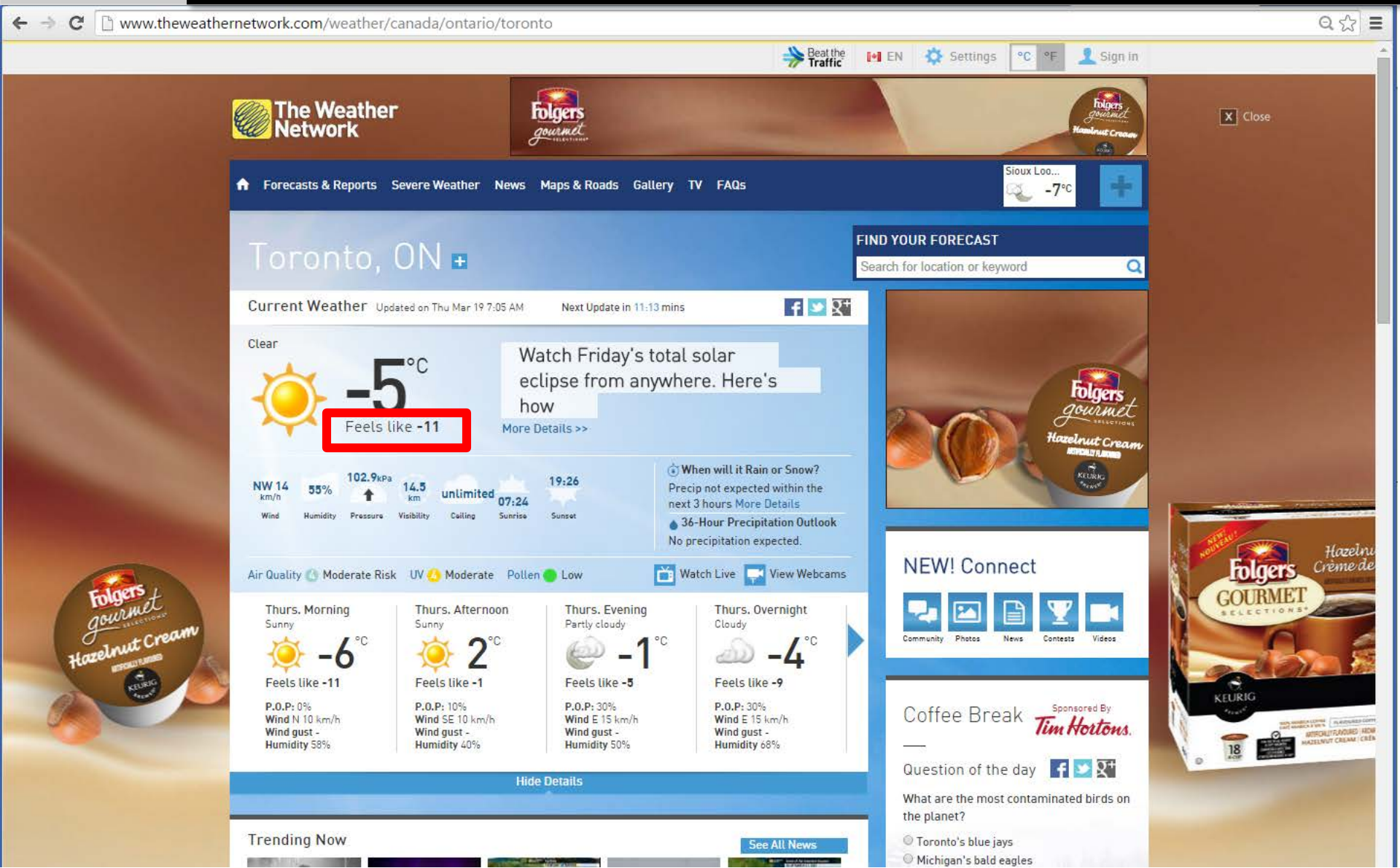
You will need to download .epw climate data for your city from this website

http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

Choose Comfort Model

- Buildings are designed for their use, occupancy or occupants
- Normally it is the people that need to be comfortable in doing their tasks, not the building
- Some uses can accommodate a much higher range of temperatures than others
- Decide if using a fully automated heating AND cooling system
- Can the building **eliminate an A/C system** due to climate?
- Can the building **use passive solar to heat** the building?
- Can the building **use passive ventilation** to cool the building?
- Can the building **take advantage of daylight** to light the building?

Thermal Comfort Models



Thermal Comfort Models

Index	Parameters	Observations
Wind Chill	Air Temperature, Wind Velocity	Winter outdoor comfort
Humidex	Air Temperature, Dew Point	Summer outdoor comfort
PMV/PPD	Wind, temperature, RH, activity, clothing	Wide acceptance Only good for indoors
Adaptive Comfort	Consider the above plus outdoor temperature	Begins to the add the dimension of perception to the equation
WBGT	RH, air temperature, radiation, (wind speed)	Used to define heat stress on a body
PET	RH, air temperature, radiation, wind speed	Defines conditions to an equivalent indoor T.
SPMV	Wind, sun, temperature, RH, activity, clothing, solar exposure	Outdoor comfort index

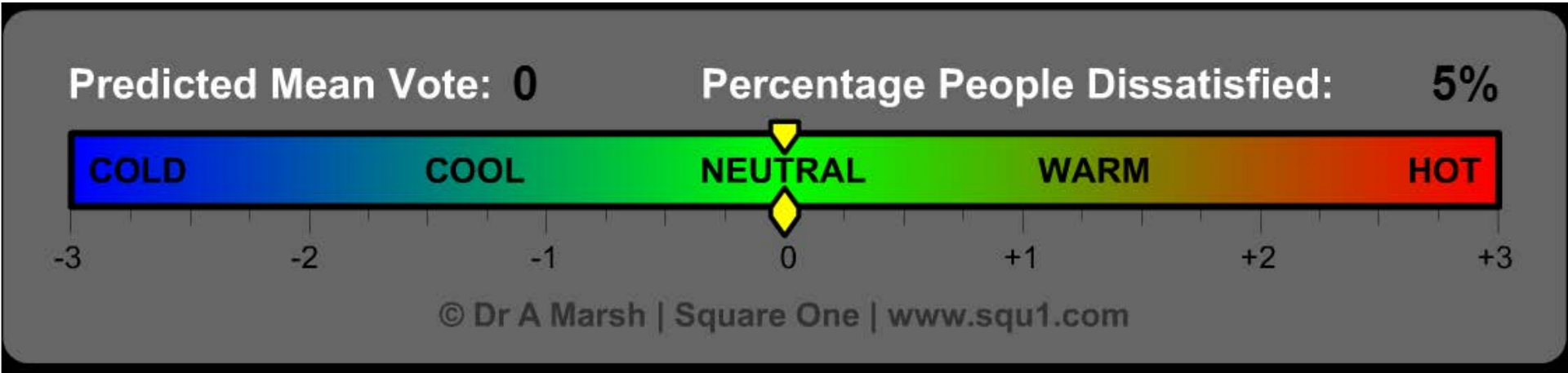
PMV/PPD

Predicted Mean Vote (PMV)

Study asked subject to rate there thermal sensation on a scale of -3 to 3, 0 is optimal when exposed to a combination of air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation.

Predicted Percentage of Dissatisfied (PPD)

The relation of PMV to estimate the PPD. ASHRAE-55 requires at least 80%.



PMV/PPD – Mean Radiant Temperature

The mean radiant temperature (MRT) is a means of expressing the influence of surface temperatures on occupant comfort.

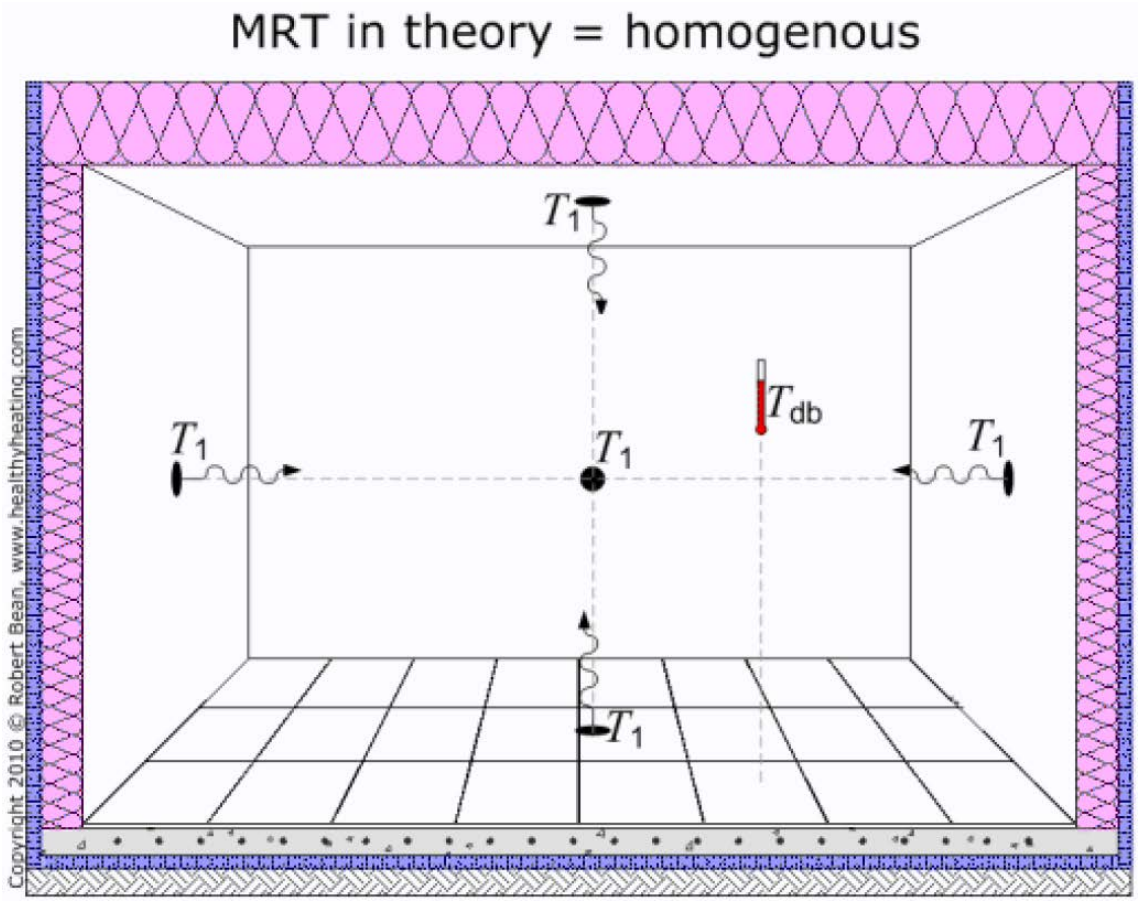
$$T_{mr} = T_1A_1 + T_2A_2 + \ldots + T_NA_N / (A_1 + A_2 + \ldots + A_N)$$

where,

T_{mr} = mean radiant temperature, °R

T_N = surface temperature of surface N, °R (calculated or measured)

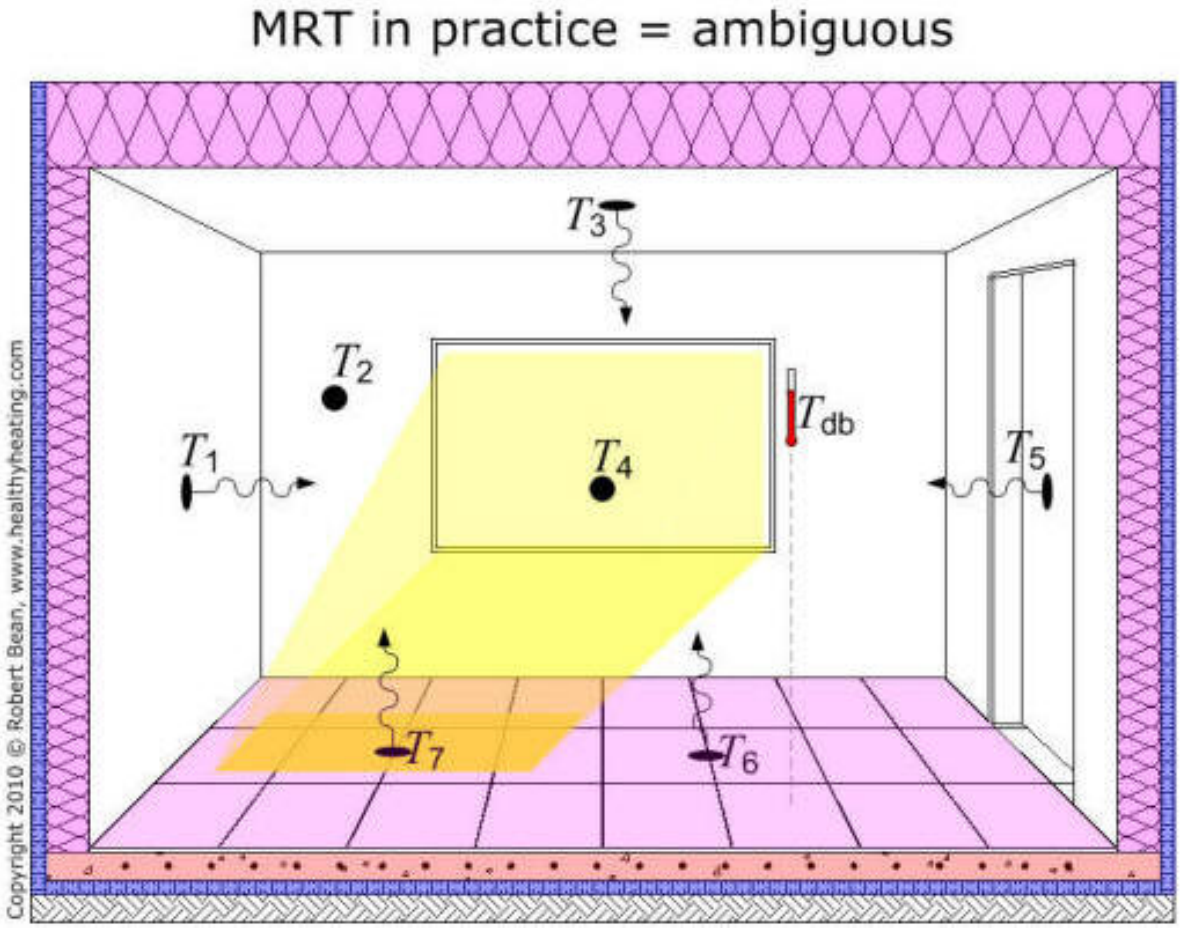
A_N = area of surface



http://www.healthyheating.com/Definitions/Mean%20Radiant.htm#.VQnM6I7F8Zs.

PMV/PPD – Mean Radiant Temperature

However...

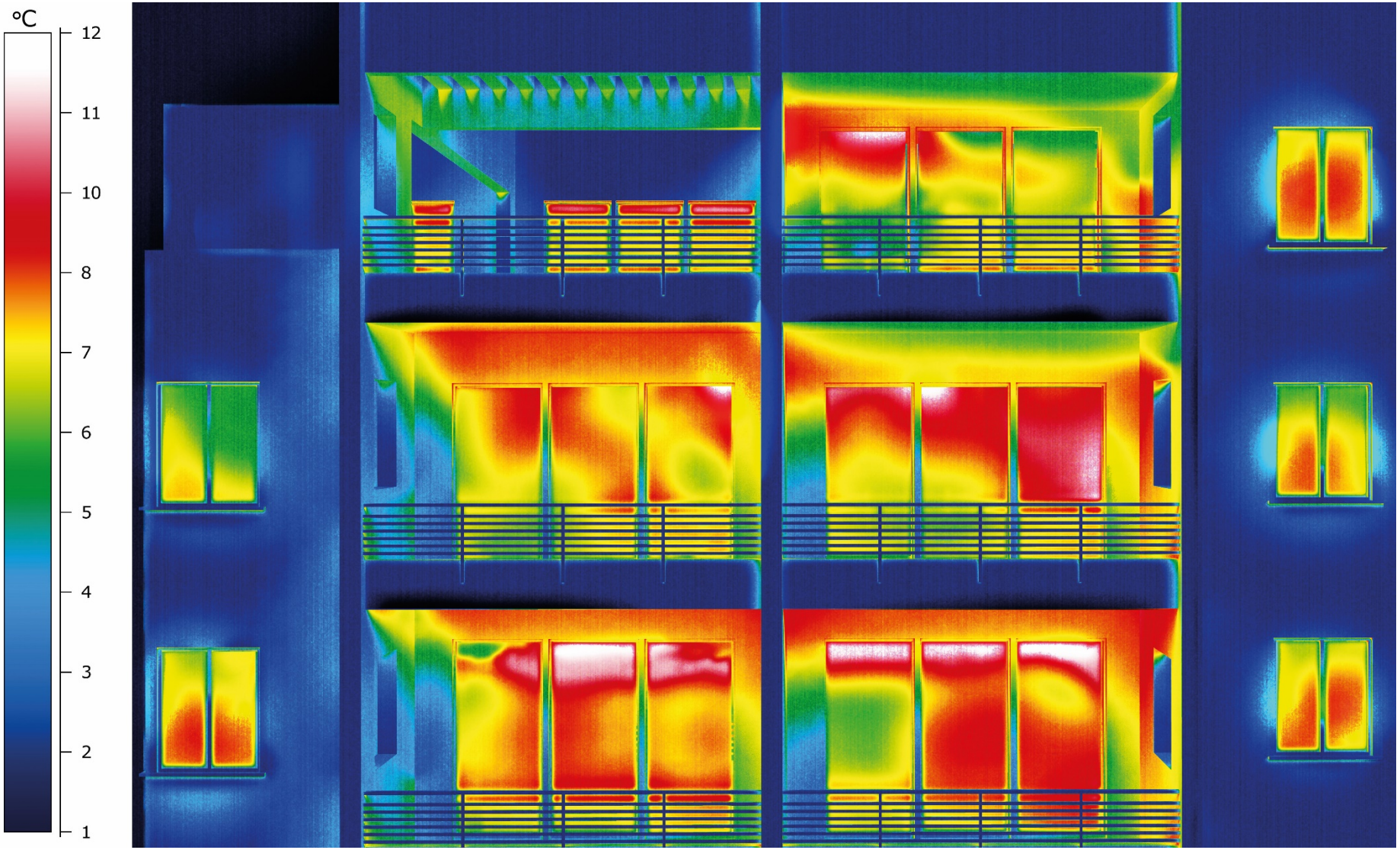


http://www.healthyheating.com/Definitions/Mean%20Radiant.htm#.VQnM6I7F8Zs.

PMV/PPD – Mean Radiant Temperature

Air Temperature = MRT is ok for interior spaces but really begins to fall apart at the perimeter largely due to thermal bridging & direct solar gain.

PMV/PPD – Mean Radiant Temperature



https://testoltd.wordpress.com/2013/03/26/thermal-imaging-resolution-matters-simply-see-more/

ASHRAE ADAPTIVE COMFORT

The adaptive model is based on the idea that outdoor climate influences indoor comfort because

humans can adapt

to different temperatures during different times of the year.

ASHRAE ADAPTIVE COMFORT

Field studies were used to show that access to environmental controls, and past thermal history influence building occupants' thermal expectations and preferences.

Choose Comfort Model

ASHRAE Handbook of Comfort Fundamentals 2005

For people dressed in normal winter clothes,

Effective Temperatures of 68°F (20°C) to 74°F (23.3°C) (measured at 50% relative humidity), which means the temperatures decrease slightly as humidity rises.

The upper humidity limit is 64°F (17.8°C) Wet Bulb and a lower Dew Point of 36F (2.2°C).

If people are dressed in light weight summer clothes then this comfort zone shifts 5°F (2.8°C) warmer.

ASHRAE Standard 55-2004 Using Predicted Mean Vote Model

Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature.

Indoors it is assumed that mean radiant temperature is close to dry bulb temperature.

The zone in which most people are comfortable is calculated using the PMV model.

In **residential settings** people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.

Adaptive Comfort Model in ASHRAE Standard 55-2004

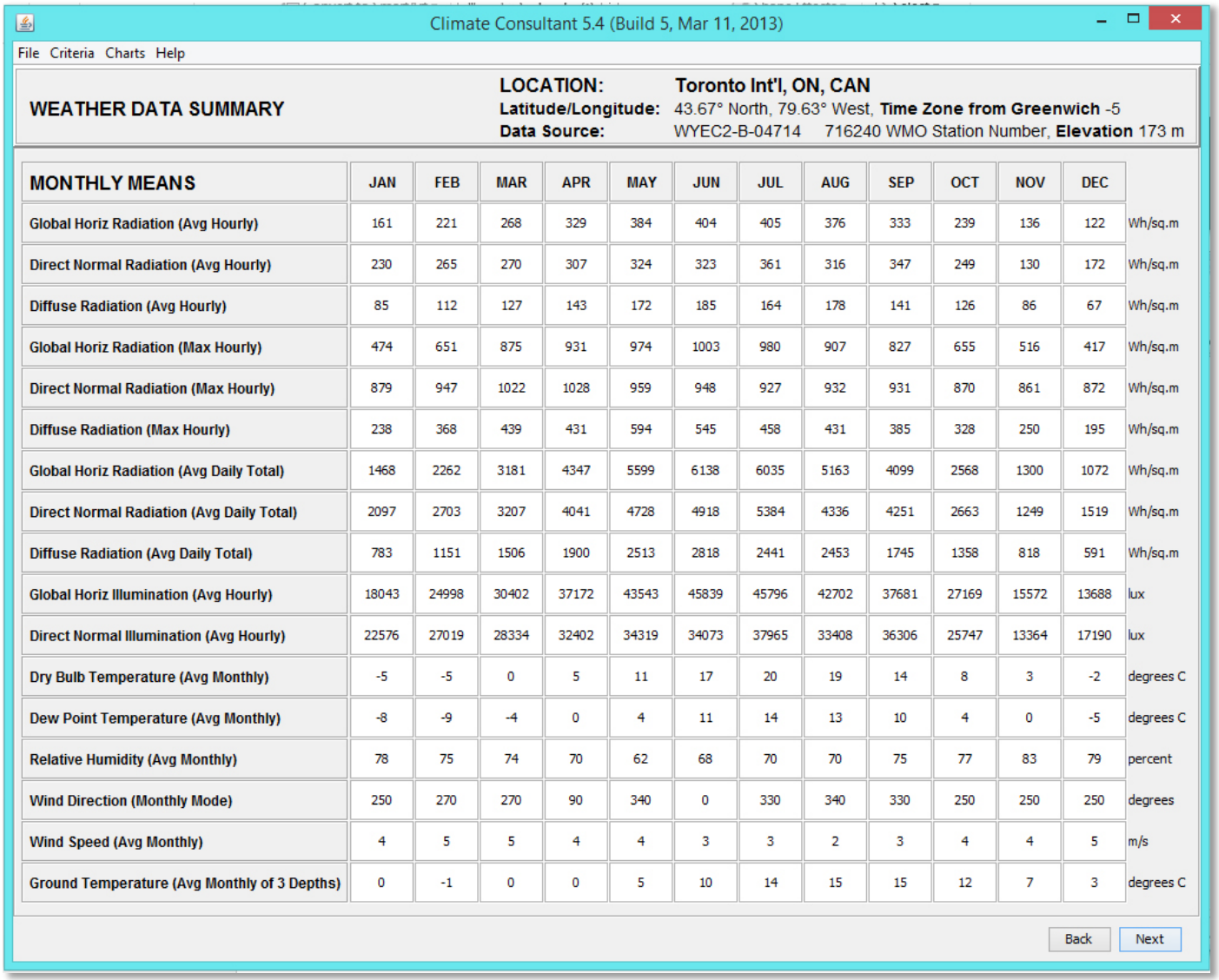
In naturally ventilated spaces where occupants can open and close windows, their thermal response will depend in part on the outdoor climate, and may have a wider comfort range than in buildings with centralized HVAC systems.

This model assumes occupants adapt their clothing to thermal conditions, and are sedentary.

There must be no mechanical Cooling System, so this method does not apply if a Mechanical Heating System is in operation.

The ability to completely eliminate a Mechanical Cooling System has great potential for Carbon savings, but comfort must be maintained passively.

EPW Weather Data for 1000s of Locations



Climate Consultant 5.4 (Build 5, Mar 11, 2013)

File Criteria Charts Help

WEATHER DATA SUMMARY

LOCATION: **Toronto Int'l, ON, CAN**
Latitude/Longitude: 43.67° North, 79.63° West, **Time Zone from Greenwich** -5
Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 173 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	161	221	268	329	384	404	405	376	333	239	136	122	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	230	265	270	307	324	323	361	316	347	249	130	172	Wh/sq.m
Diffuse Radiation (Avg Hourly)	85	112	127	143	172	185	164	178	141	126	86	67	Wh/sq.m
Global Horiz Radiation (Max Hourly)	474	651	875	931	974	1003	980	907	827	655	516	417	Wh/sq.m
Direct Normal Radiation (Max Hourly)	879	947	1022	1028	959	948	927	932	931	870	861	872	Wh/sq.m
Diffuse Radiation (Max Hourly)	238	368	439	431	594	545	458	431	385	328	250	195	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	1468	2262	3181	4347	5599	6138	6035	5163	4099	2568	1300	1072	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2097	2703	3207	4041	4728	4918	5384	4336	4251	2663	1249	1519	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	783	1151	1506	1900	2513	2818	2441	2453	1745	1358	818	591	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	18043	24998	30402	37172	43543	45839	45796	42702	37681	27169	15572	13688	lux
Direct Normal Illumination (Avg Hourly)	22576	27019	28334	32402	34319	34073	37965	33408	36306	25747	13364	17190	lux
Dry Bulb Temperature (Avg Monthly)	-5	-5	0	5	11	17	20	19	14	8	3	-2	degrees C
Dew Point Temperature (Avg Monthly)	-8	-9	-4	0	4	11	14	13	10	4	0	-5	degrees C
Relative Humidity (Avg Monthly)	78	75	74	70	62	68	70	70	75	77	83	79	percent
Wind Direction (Monthly Mode)	250	270	270	90	340	0	330	340	330	250	250	250	degrees
Wind Speed (Avg Monthly)	4	5	5	4	4	3	3	2	3	4	4	5	m/s
Ground Temperature (Avg Monthly of 3 Depths)	0	-1	0	0	5	10	14	15	15	12	7	3	degrees C

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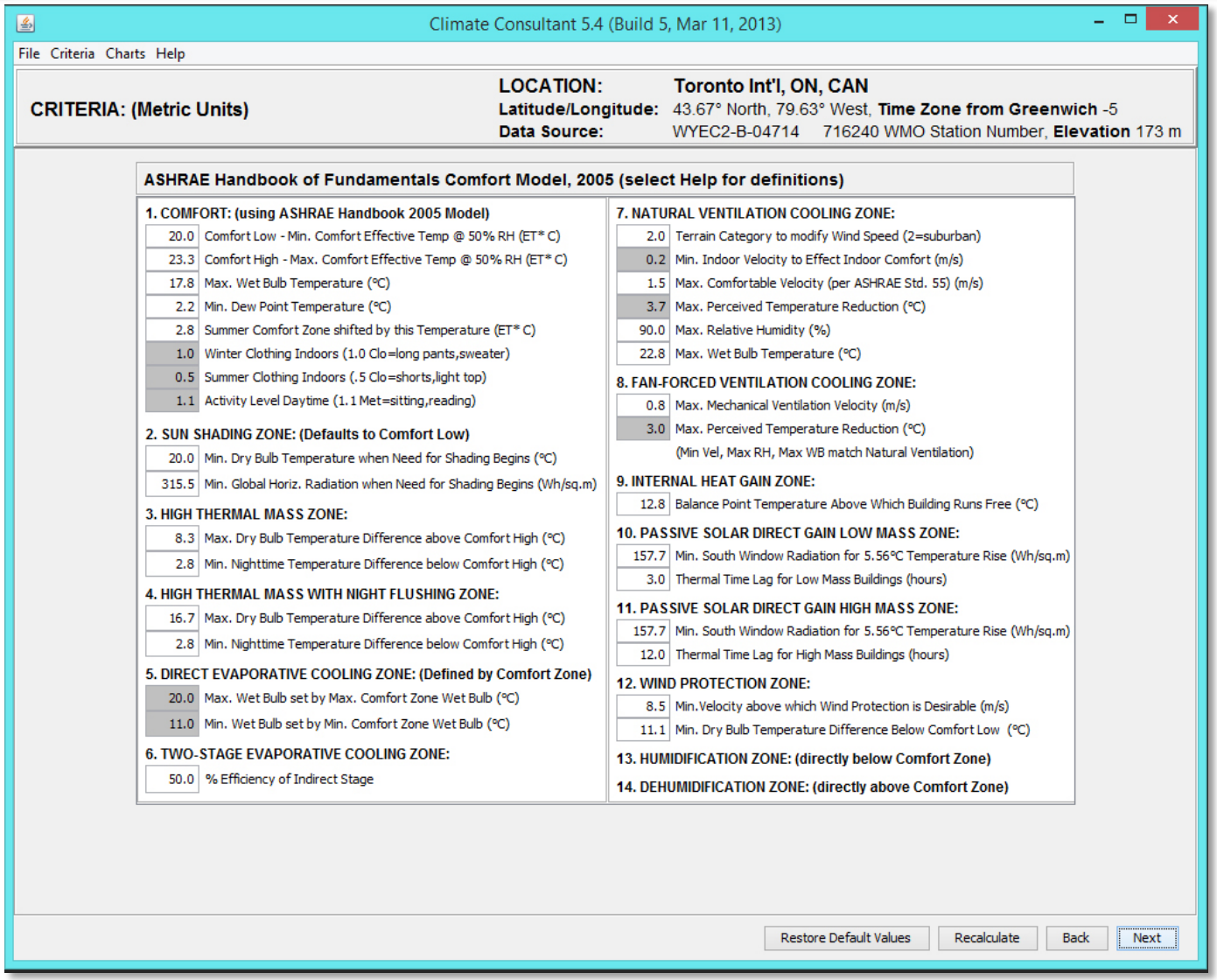
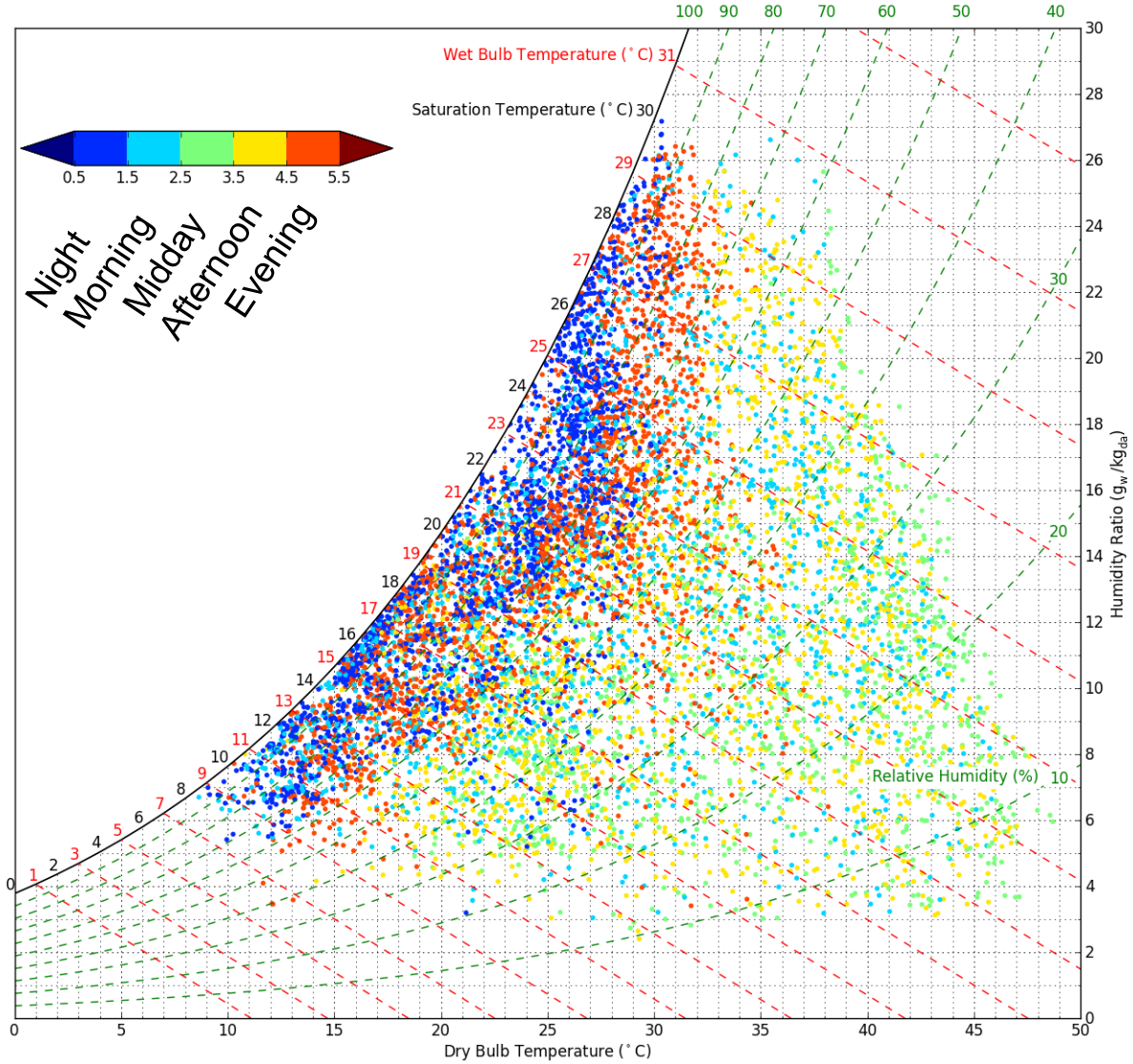
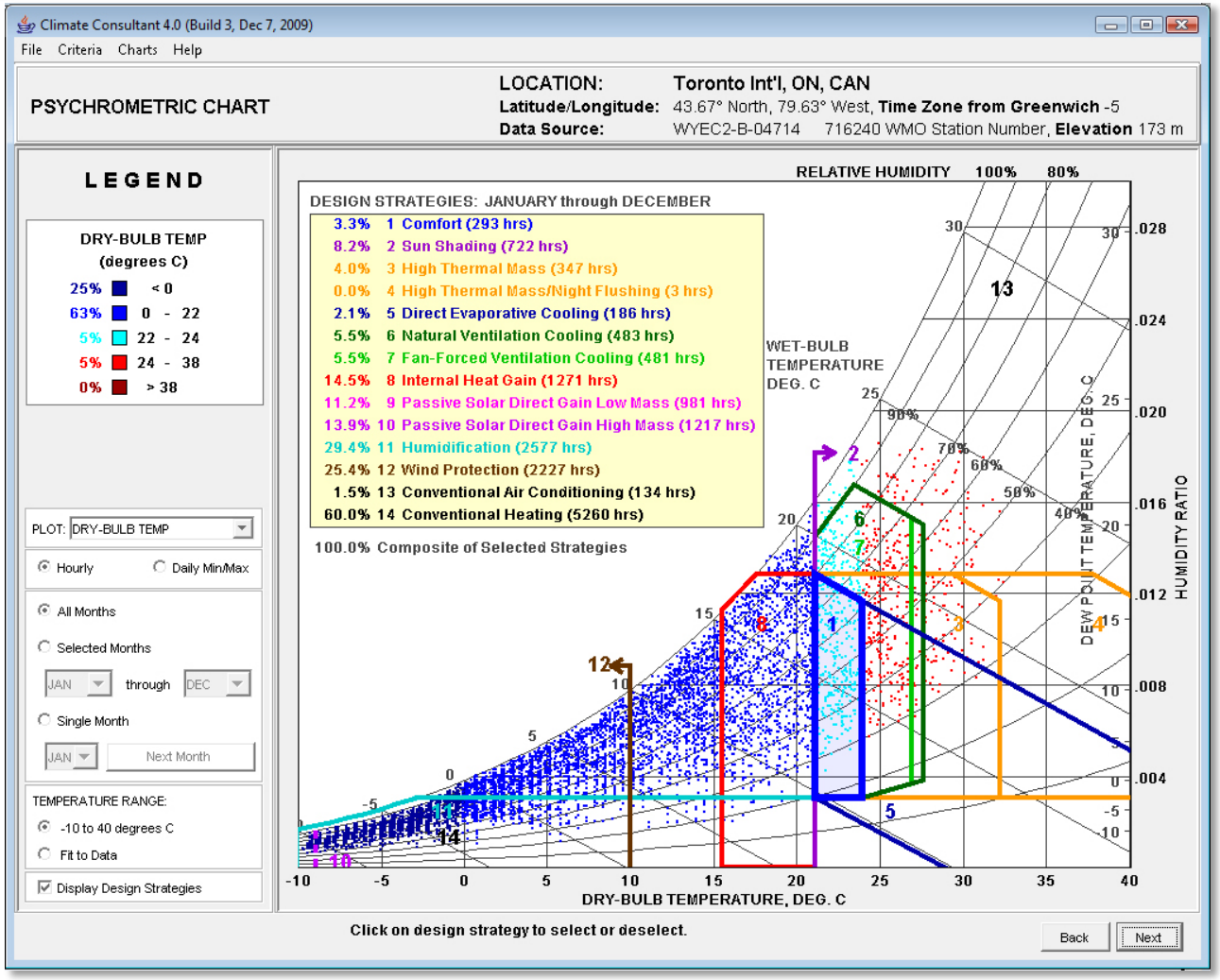
Setting the Project Criteria



The Psychrometric Chart

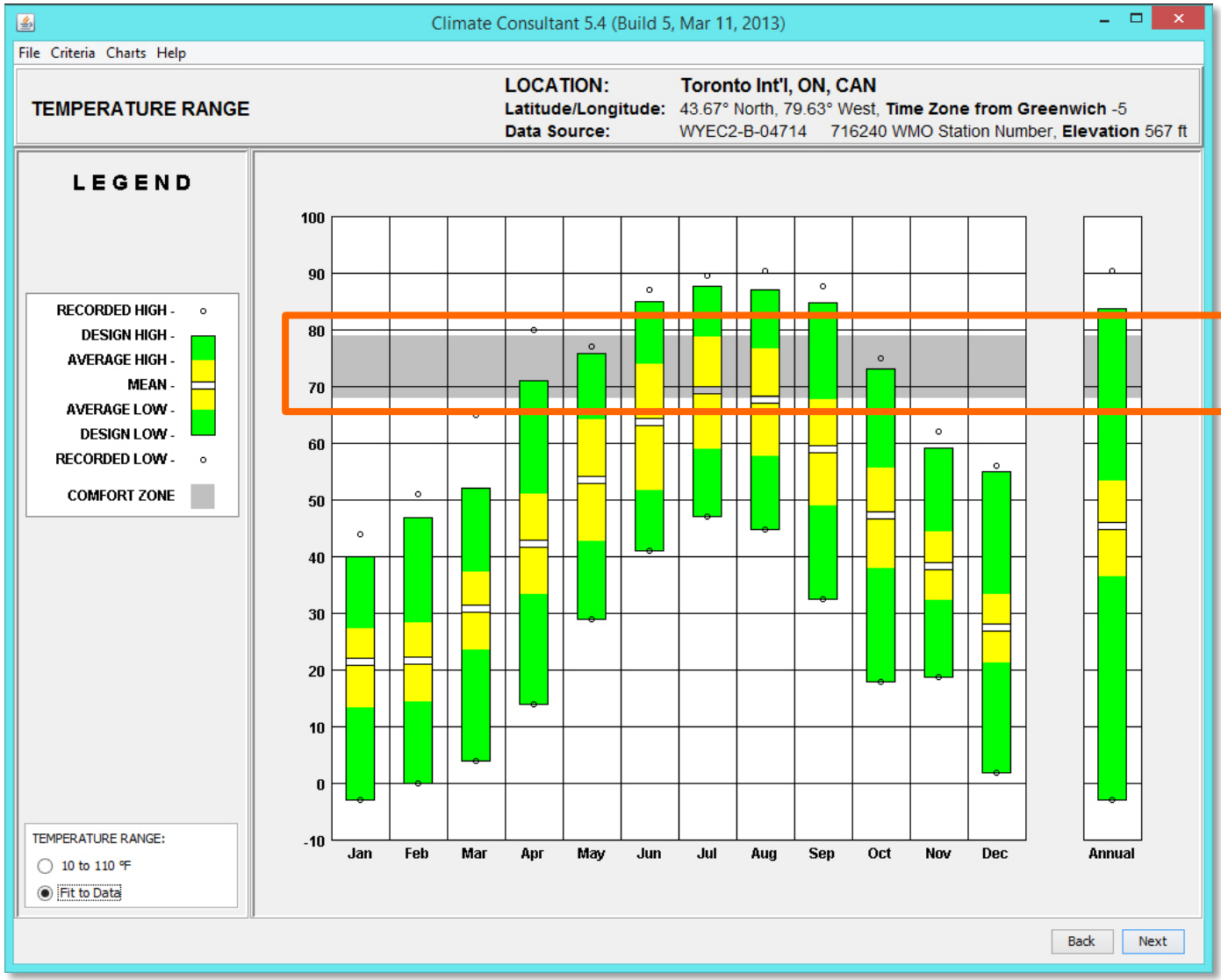


Psychrometric Chart



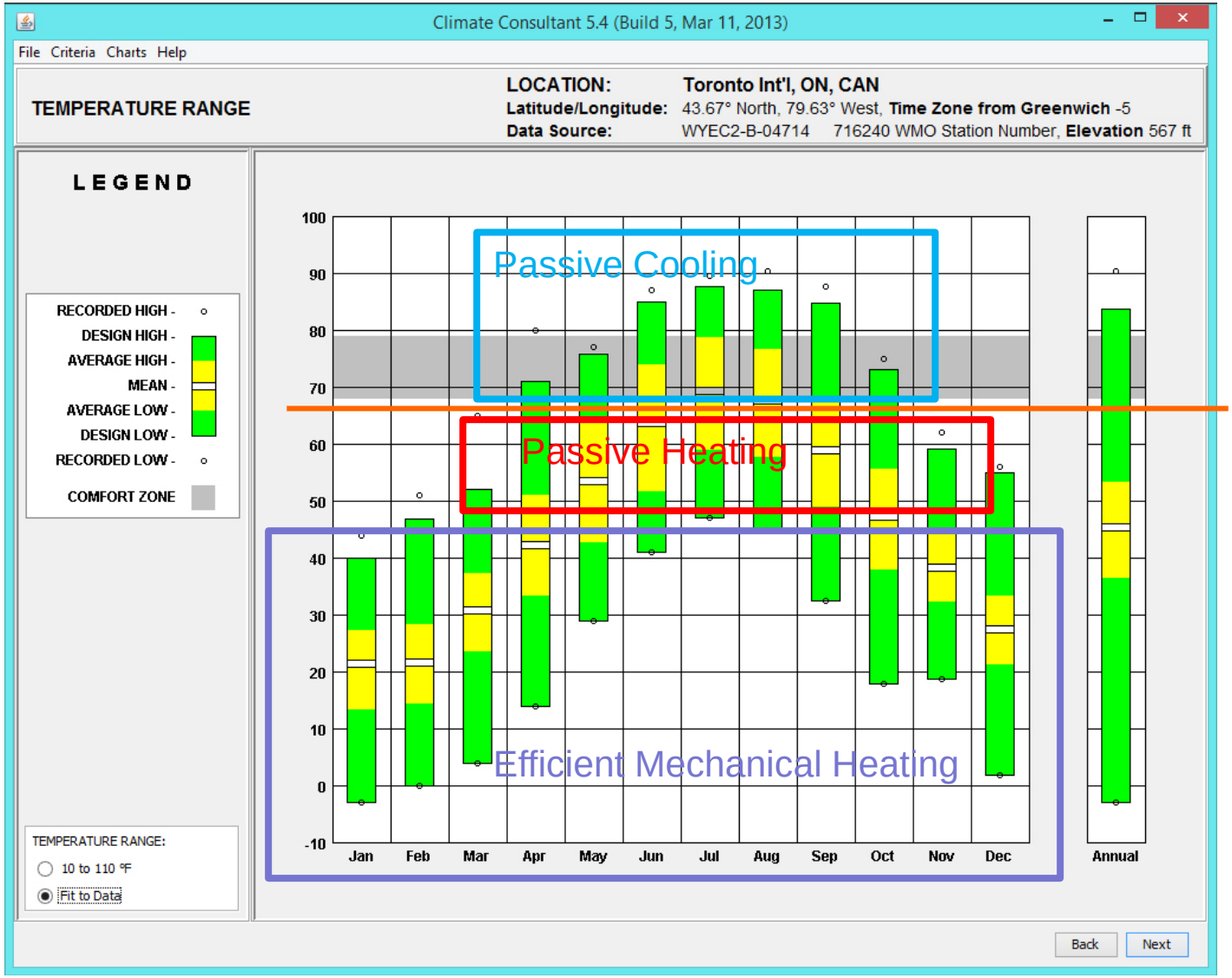
The chart helps to identify climate based strategies to achieve comfort.

Climate Data for Toronto



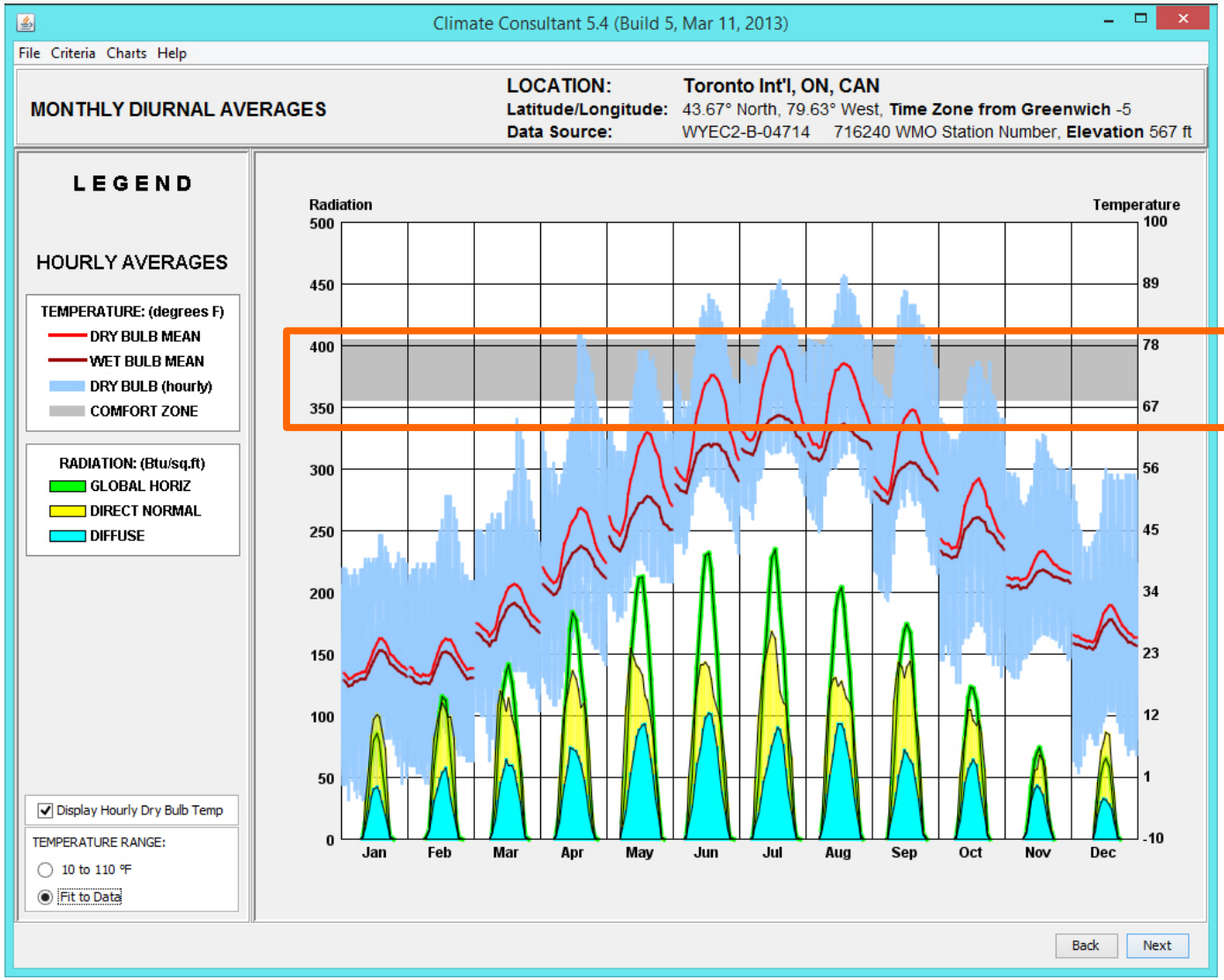
COMFORT ZONE

Climate Data for Toronto



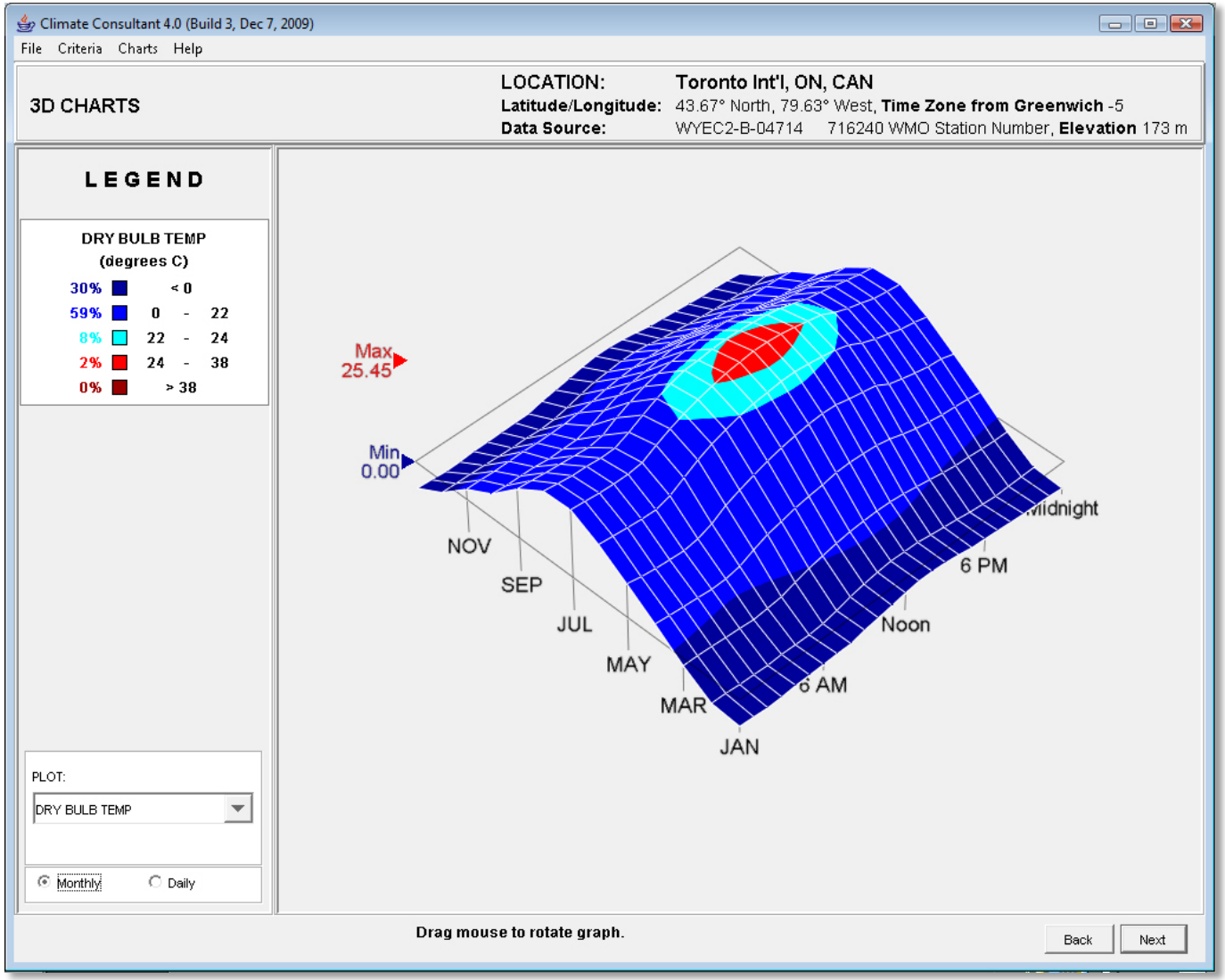
18°C is the base point for measuring Heating vs Cooling Degree days

Climate Data for Toronto

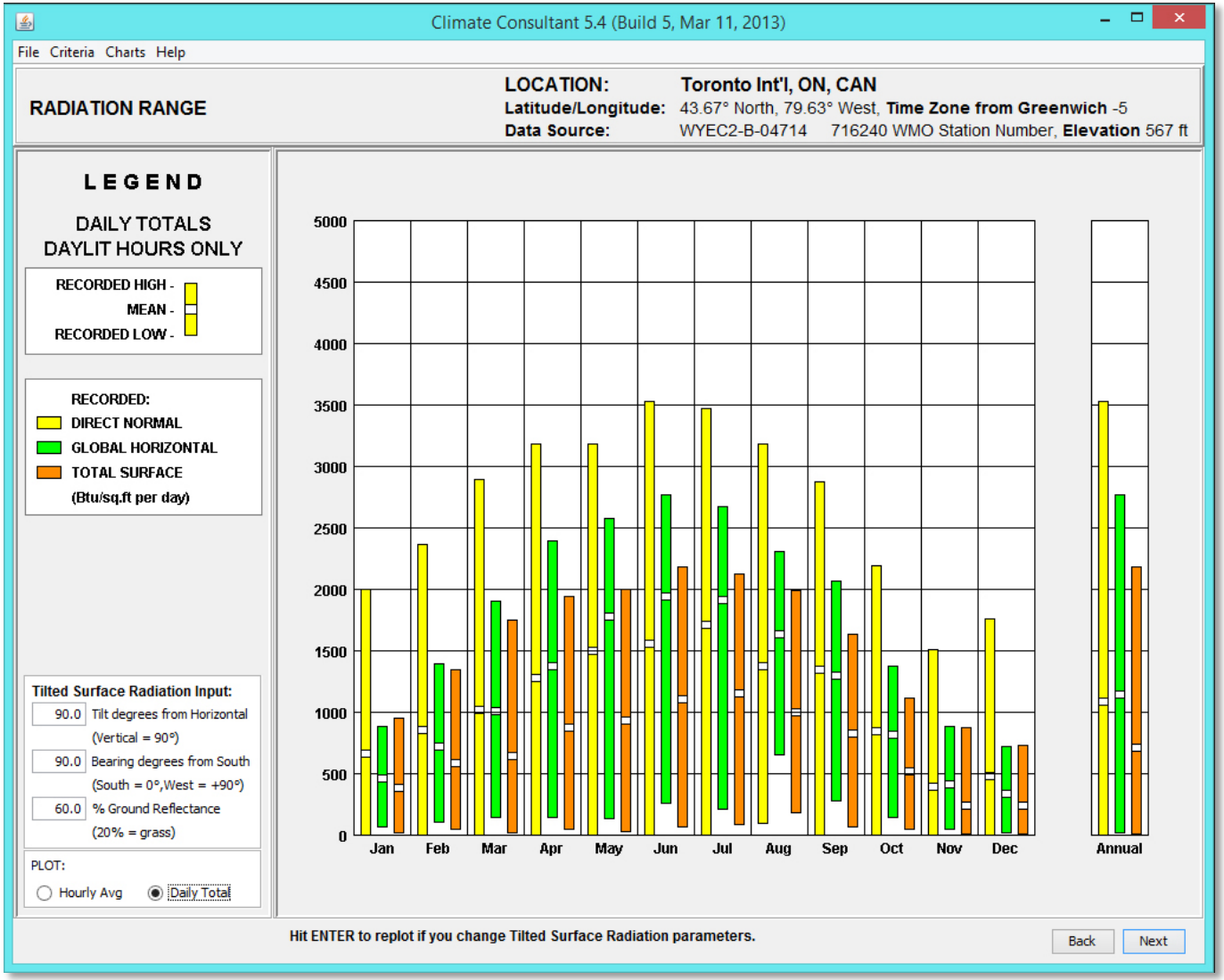


COMFORT ZONE

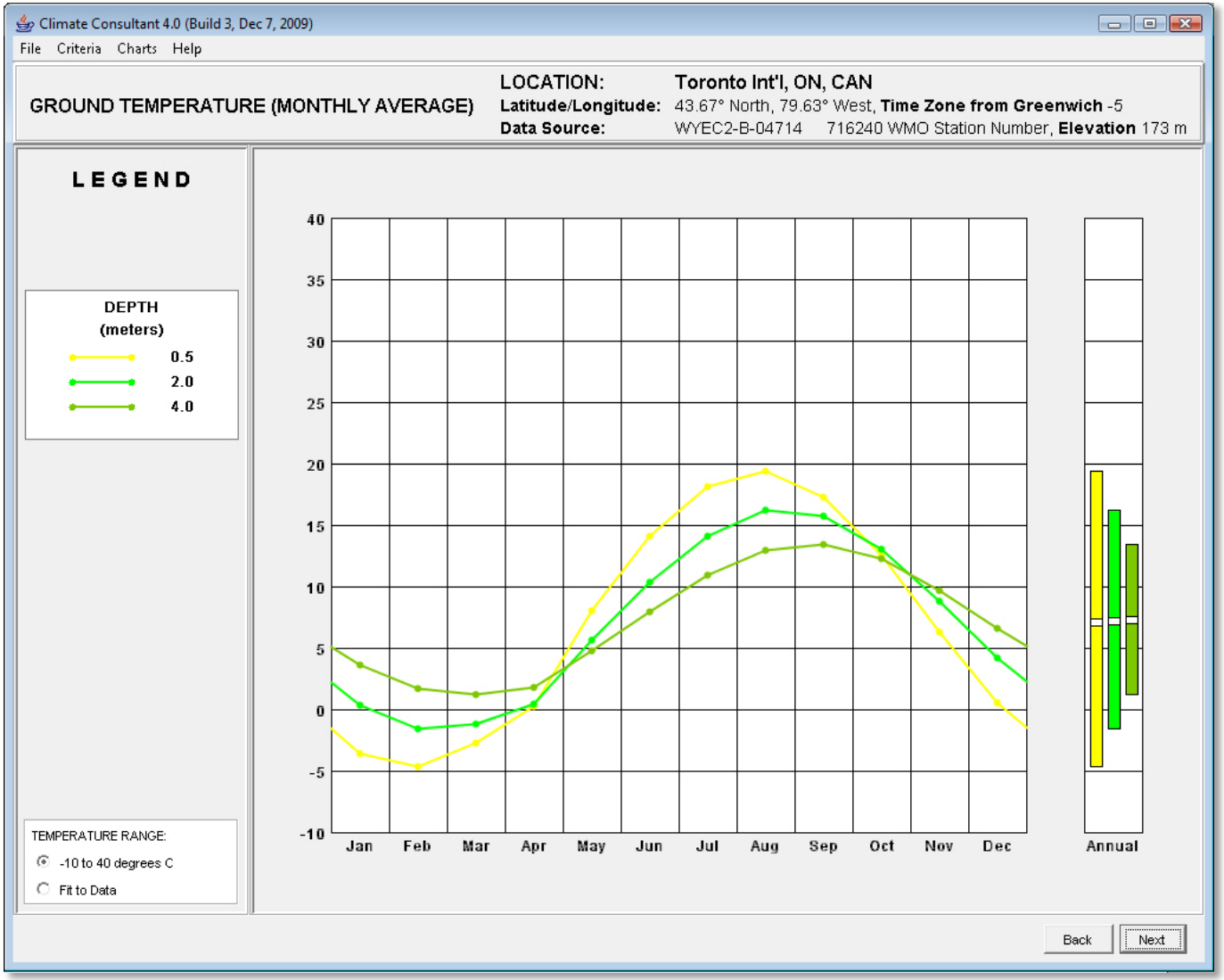
Temperature Range for Toronto



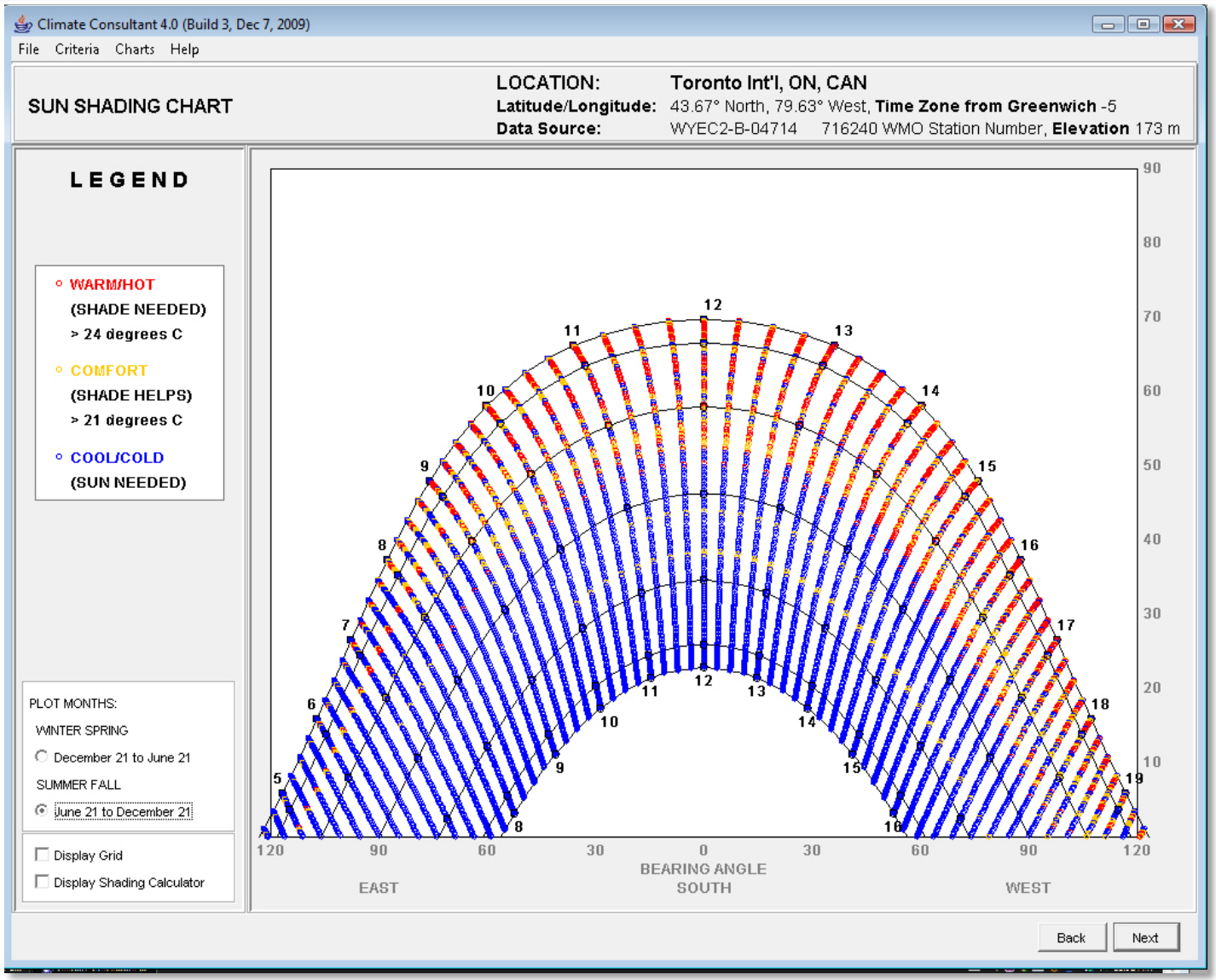
Toronto Solar Radiation Range



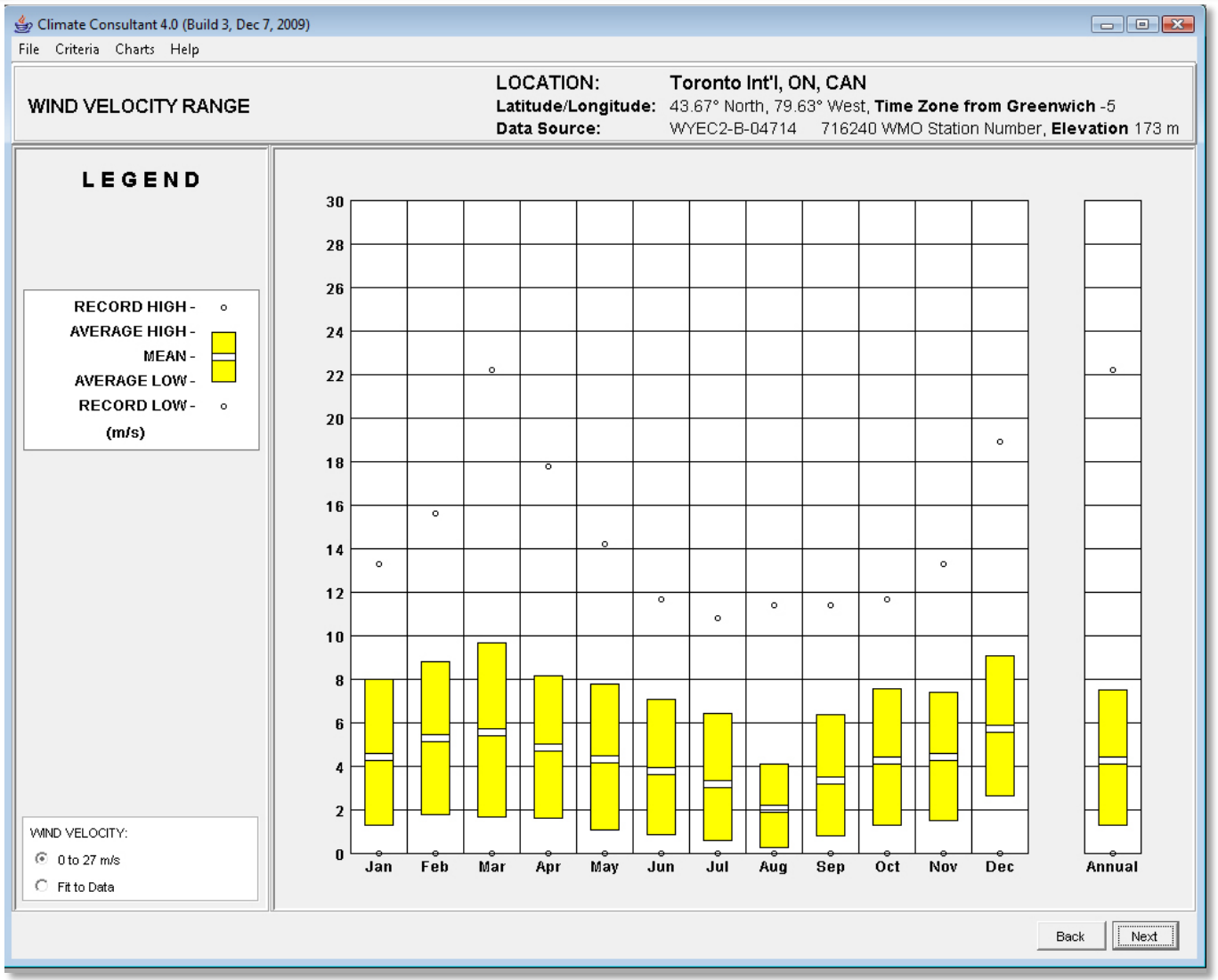
Ground Temperature for Toronto



Sun Shading Chart



Wind Speed


Climate Consultant 4.0 (Build 3, Dec 7, 2009)
File Criteria Charts Help
WIND VELOCITY RANGE
LOCATION: Toronto Int'l, ON, CAN
Latitude/Longitude: 43.67° North, 79.63° West, Time Zone from Greenwich -5
Data Source: WYEC2-B-04714 716240 WMO Station Number, Elevation 173 m
LEGEND
RECORD HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORD LOW -
(m/s)
WIND VELOCITY:
0 to 27 m/s
Fit to Data
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Annual
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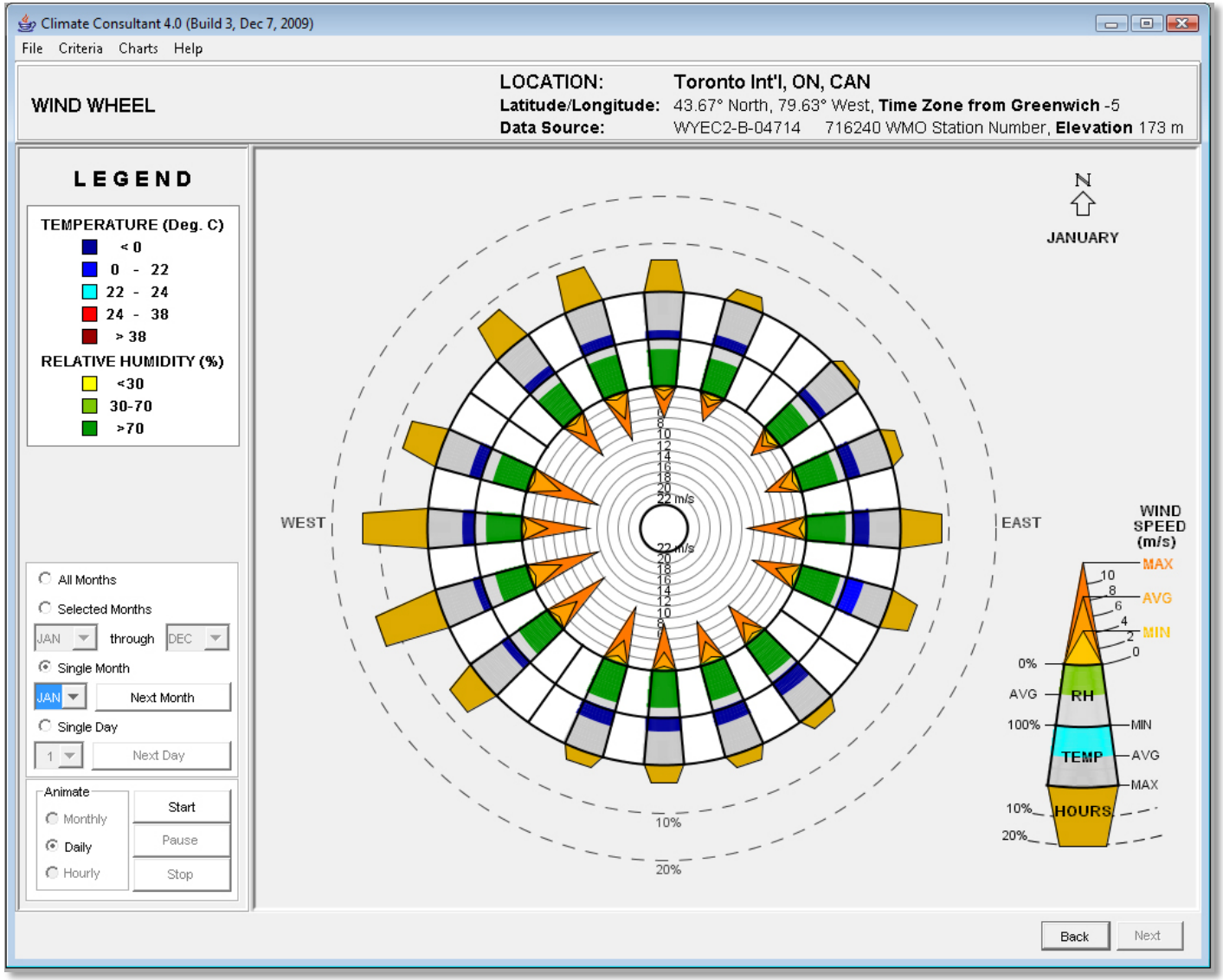
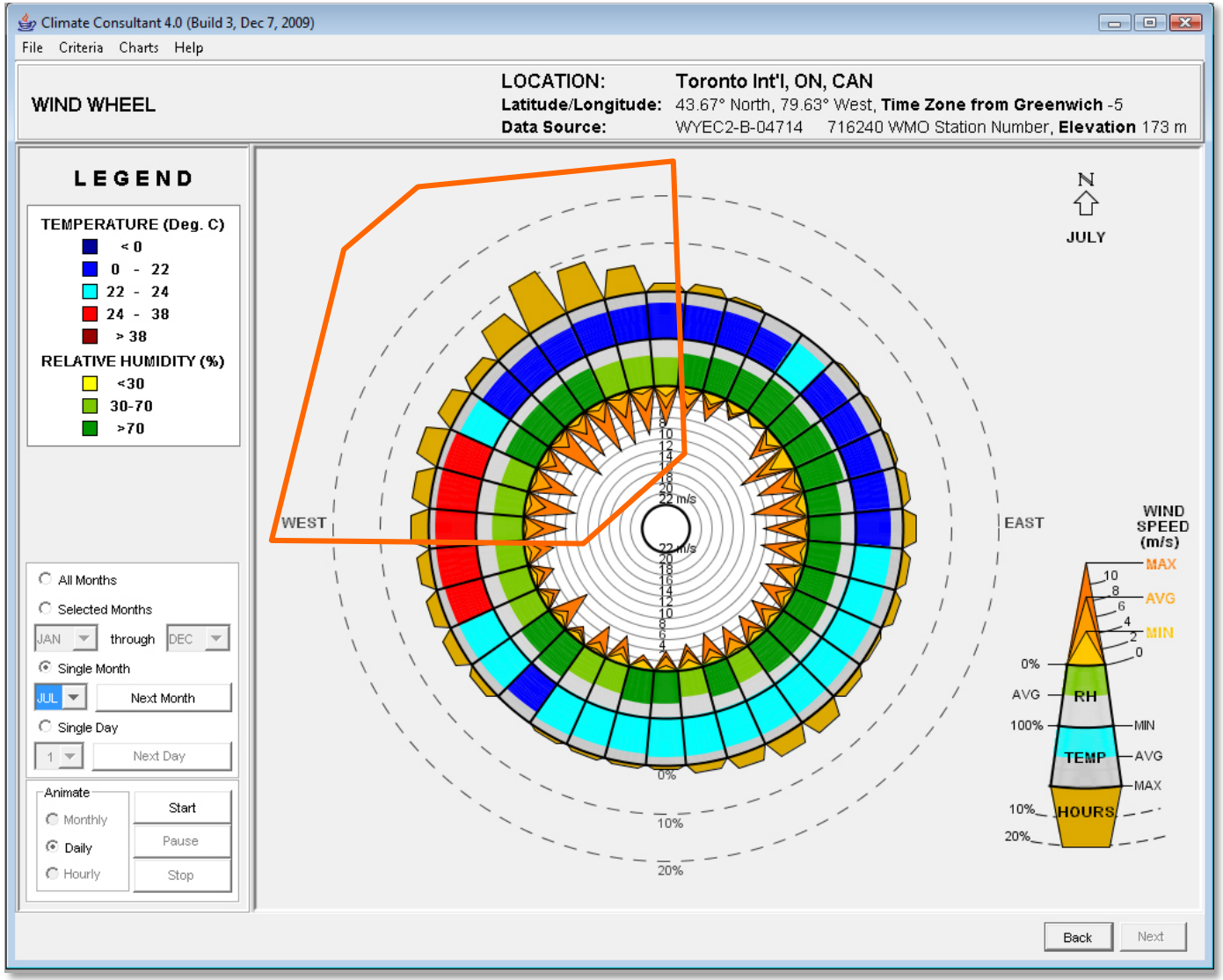
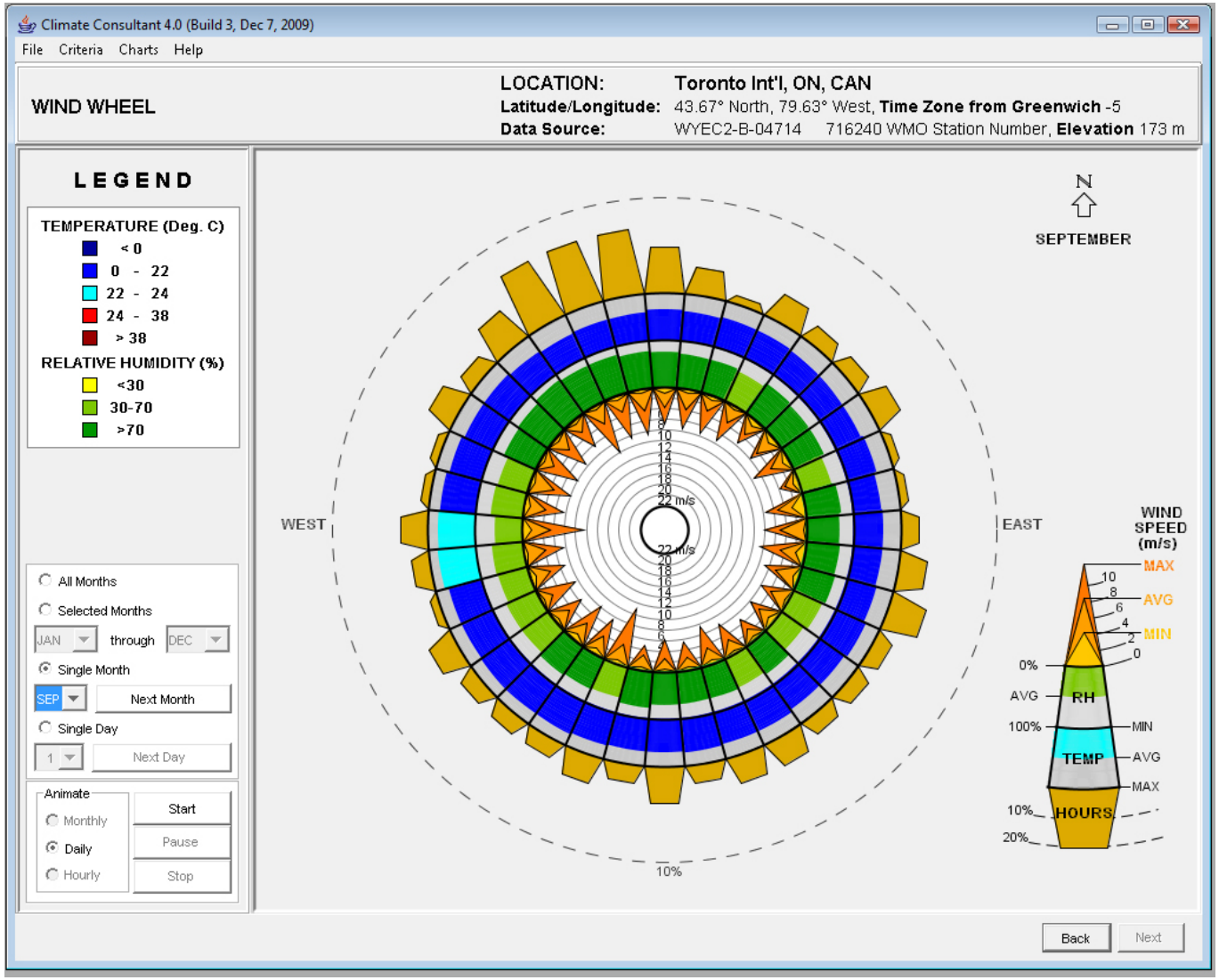
January Wind Wheel/Rose for Toronto



July Wind Wheel/Rose for Toronto



September Wind Wheel/Rose for Toronto



Source of EPW Data

Story of TMY data gathering:

- Means Typical Meteorological Year
- Collection of typical months of various years to constitute a complete year of data
- Is getting out of date as does not reflect recent climate changes
- Most accurate for solar, temperature and wind
- Not very accurate for precipitation

Bio-climatic Design: HOT-ARID RULES

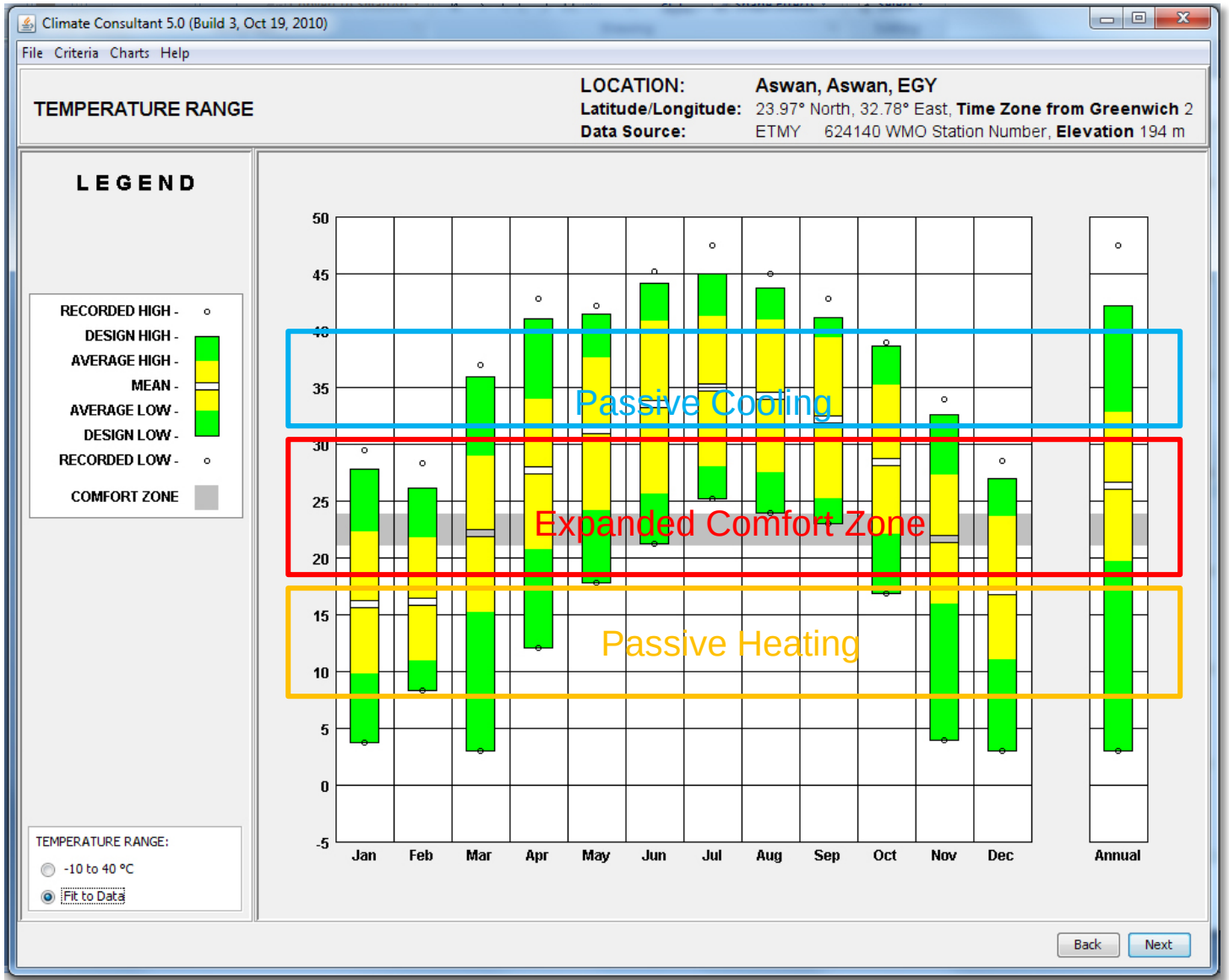
Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

Traditional House in Egypt

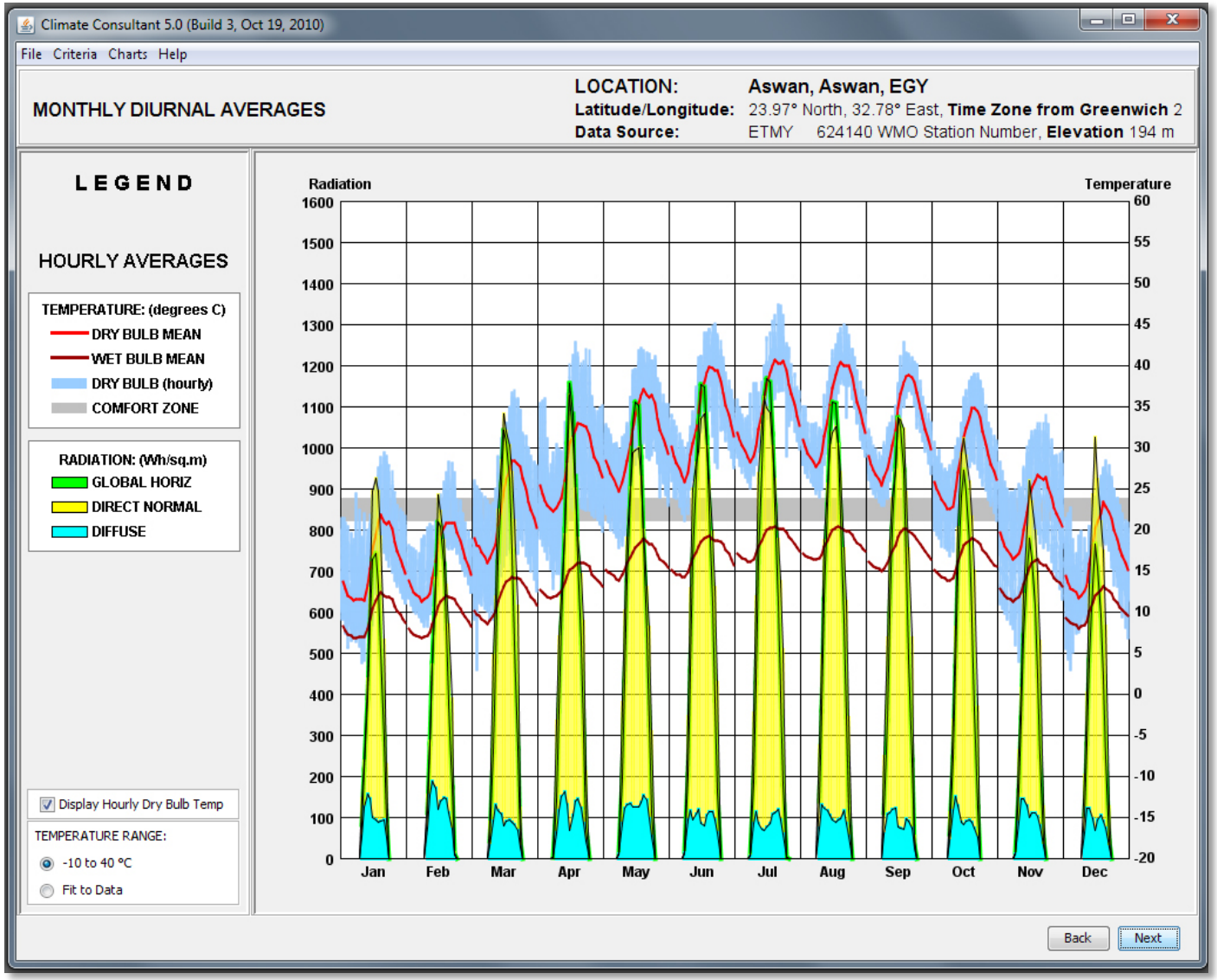
RULES:

- **SOLAR AVOIDANCE**: keep DIRECT SOLAR GAIN out of the building
- avoid daytime ventilation
- promote nighttime flushing with cool evening air
- achieve daylighting by reflectance and use of LIGHT non-heat absorbing colours
- create a cooler MICROCLIMATE by using light / lightweight materials
- respect the DIURNAL CYCLE
- use heavy mass for walls and DO NOT INSULATE

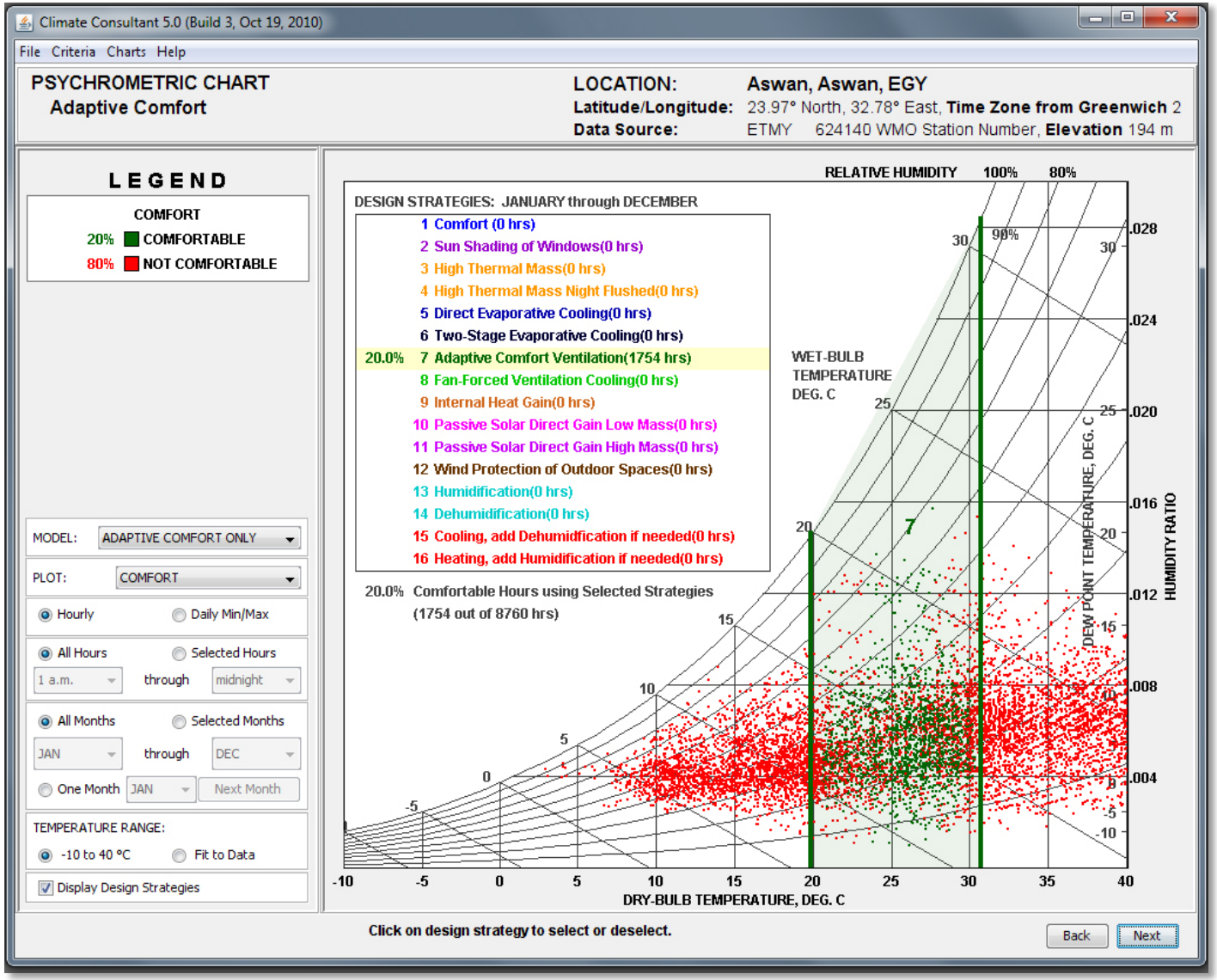
Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-HUMID

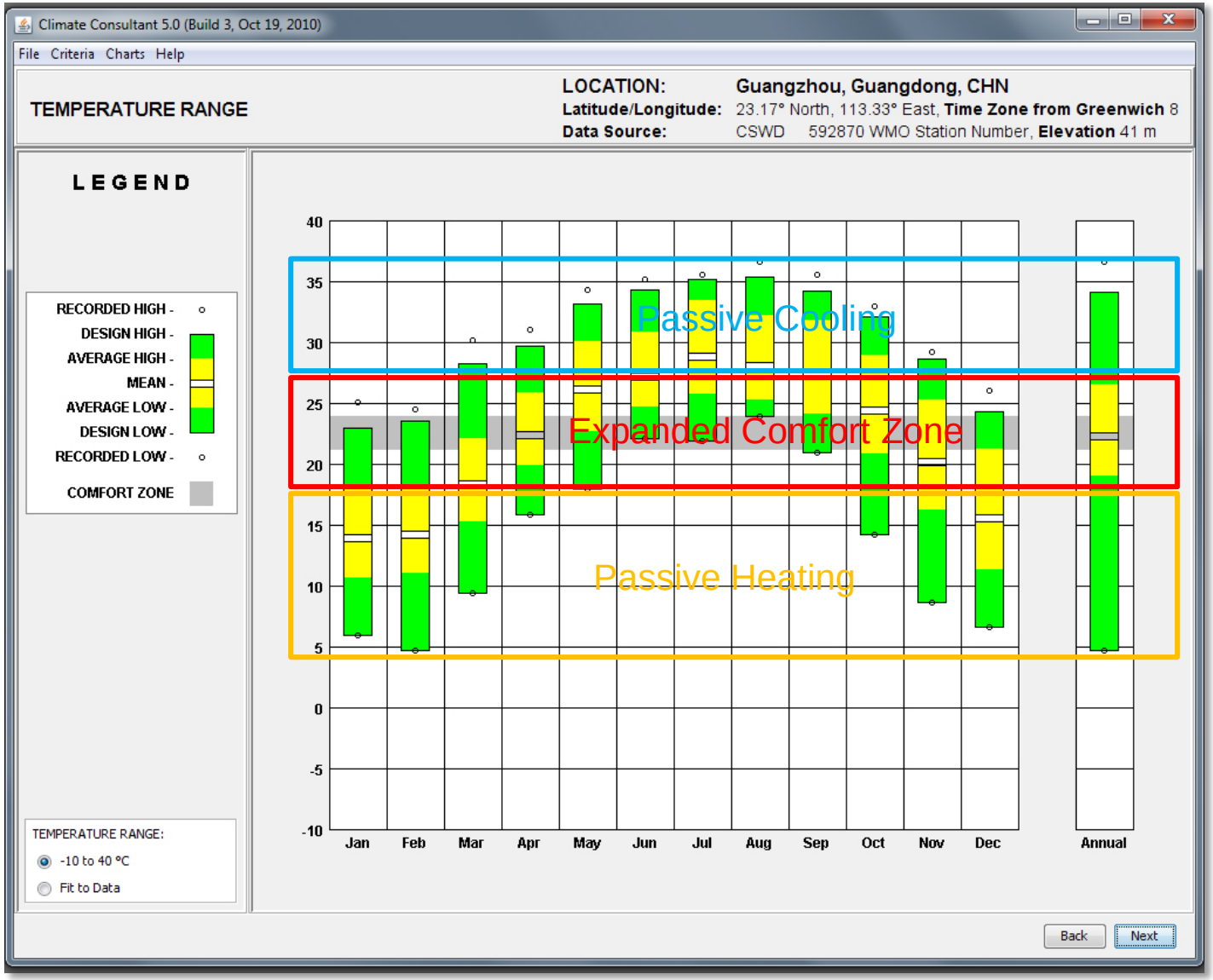
Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

House in Seaside, Florida

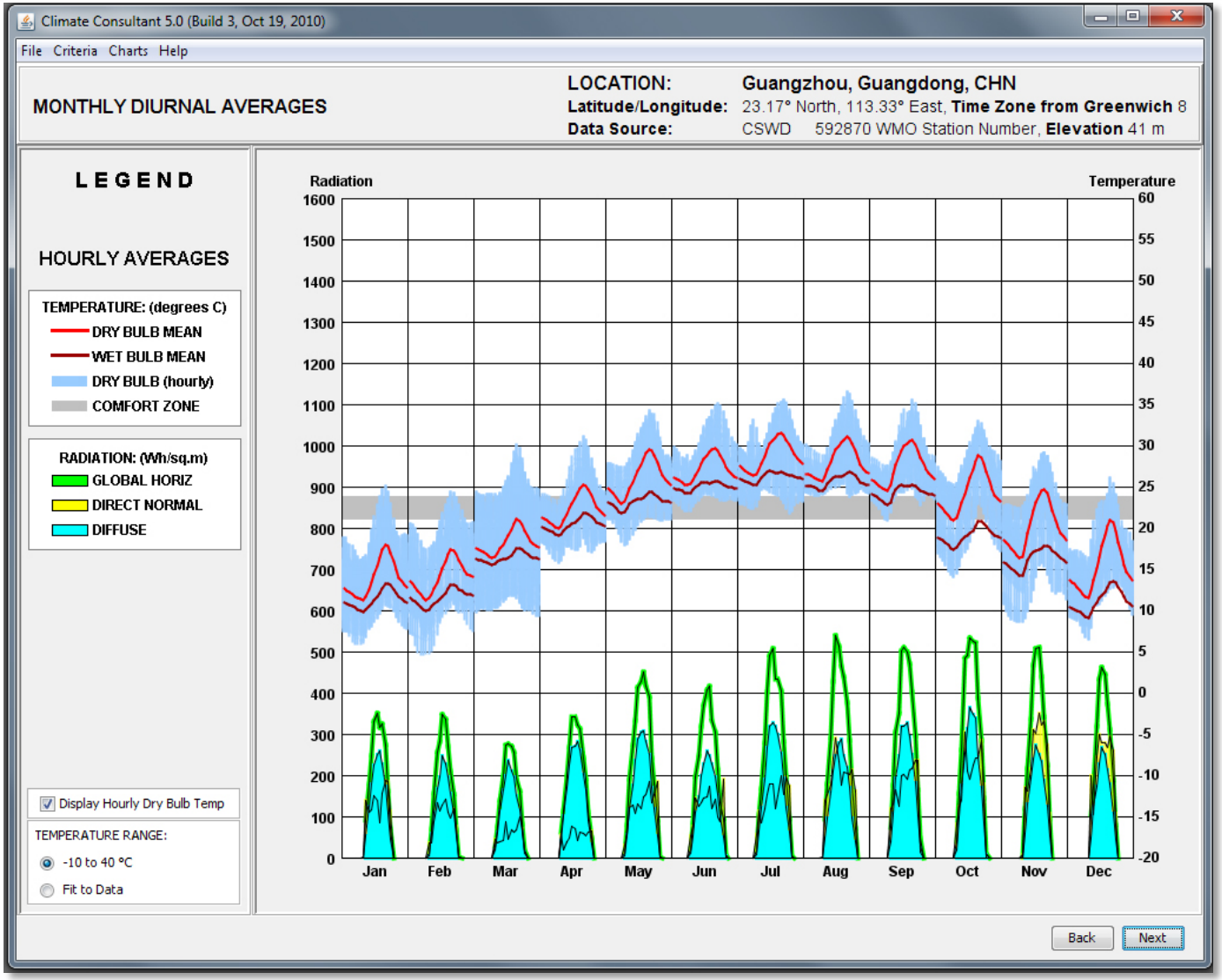
RULES:

- **SOLAR AVOIDANCE** : large roofs with overhangs that shade walls and to allow windows open at all times
- **PROMOTE VENTILATION**
- **USE LIGHTWEIGHT MATERIALS** that do not hold heat and that will not promote condensation and dampness (mold/mildew)
- *eliminate basements and concrete*
- use STACK EFFECT to ventilate through high spaces
- use of COURTYARDS and semi-enclosed outside spaces
- use WATER FEATURES for cooling

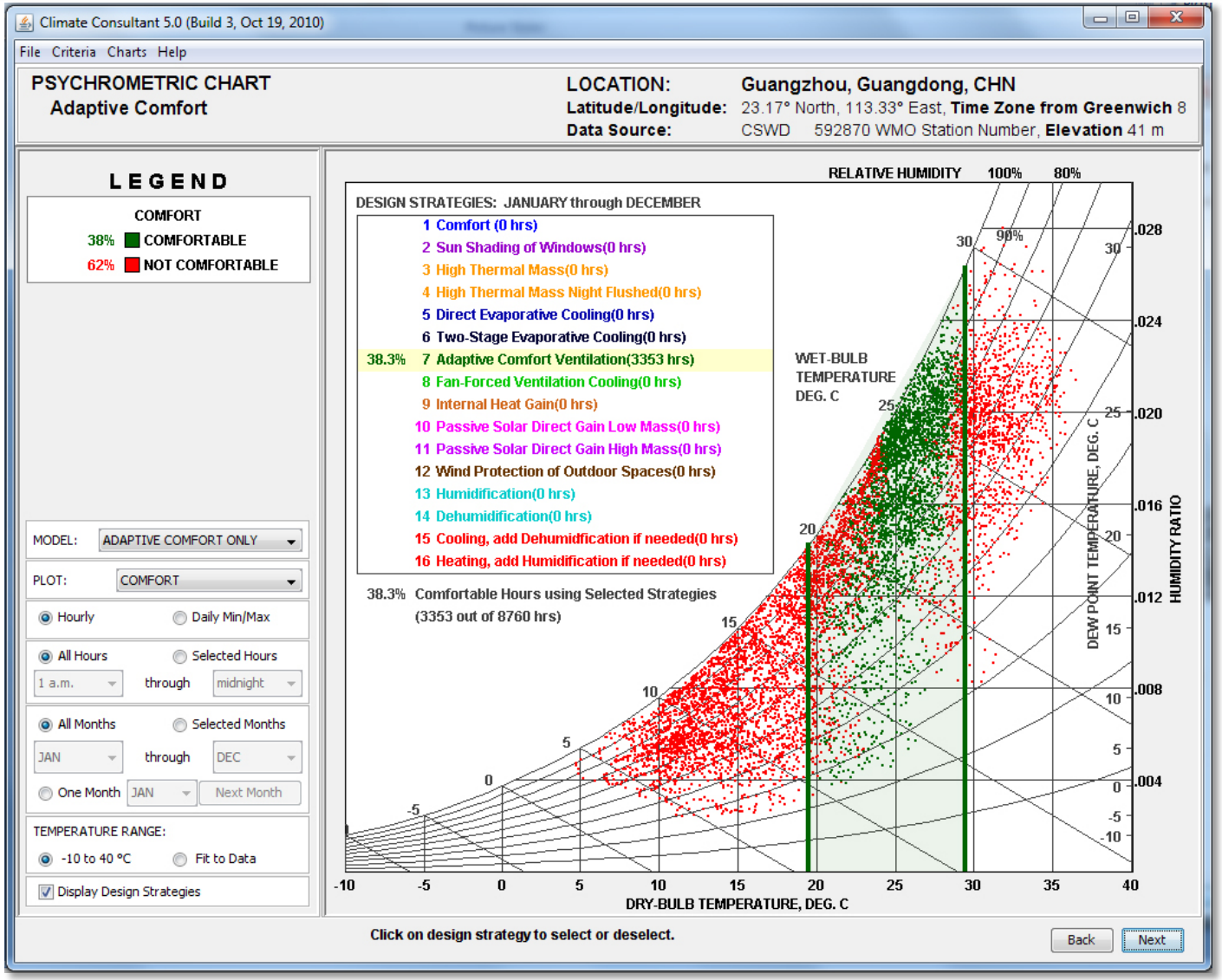
Bio-climatic Design: HOT-HUMID



Bio-climatic Design: HOT-HUMID



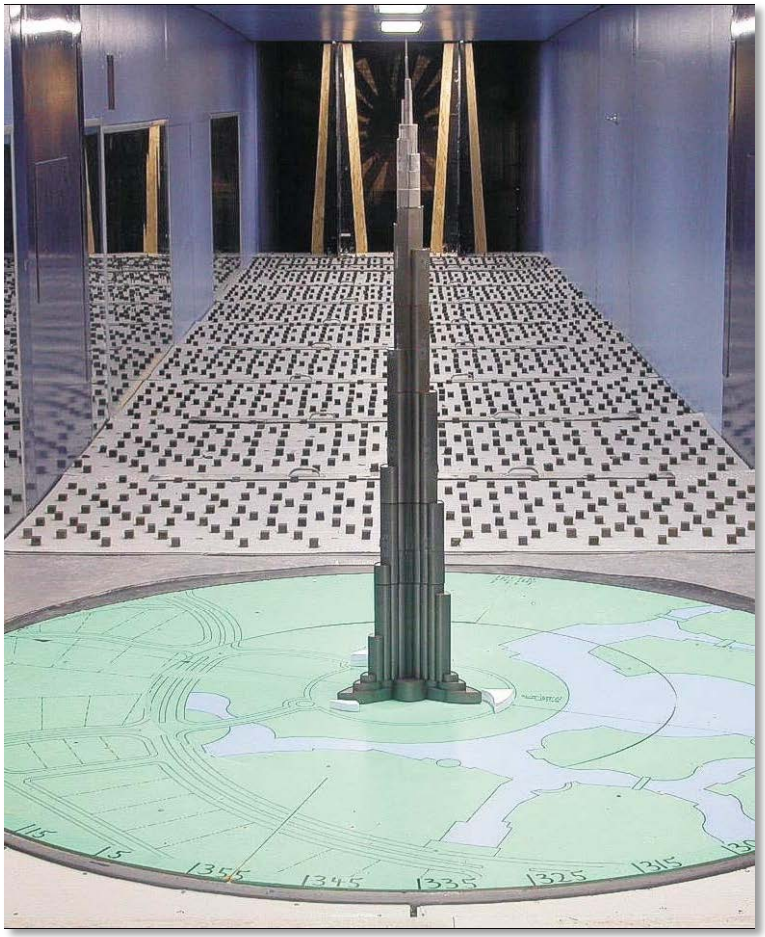
Bio-climatic Design: HOT-HUMID



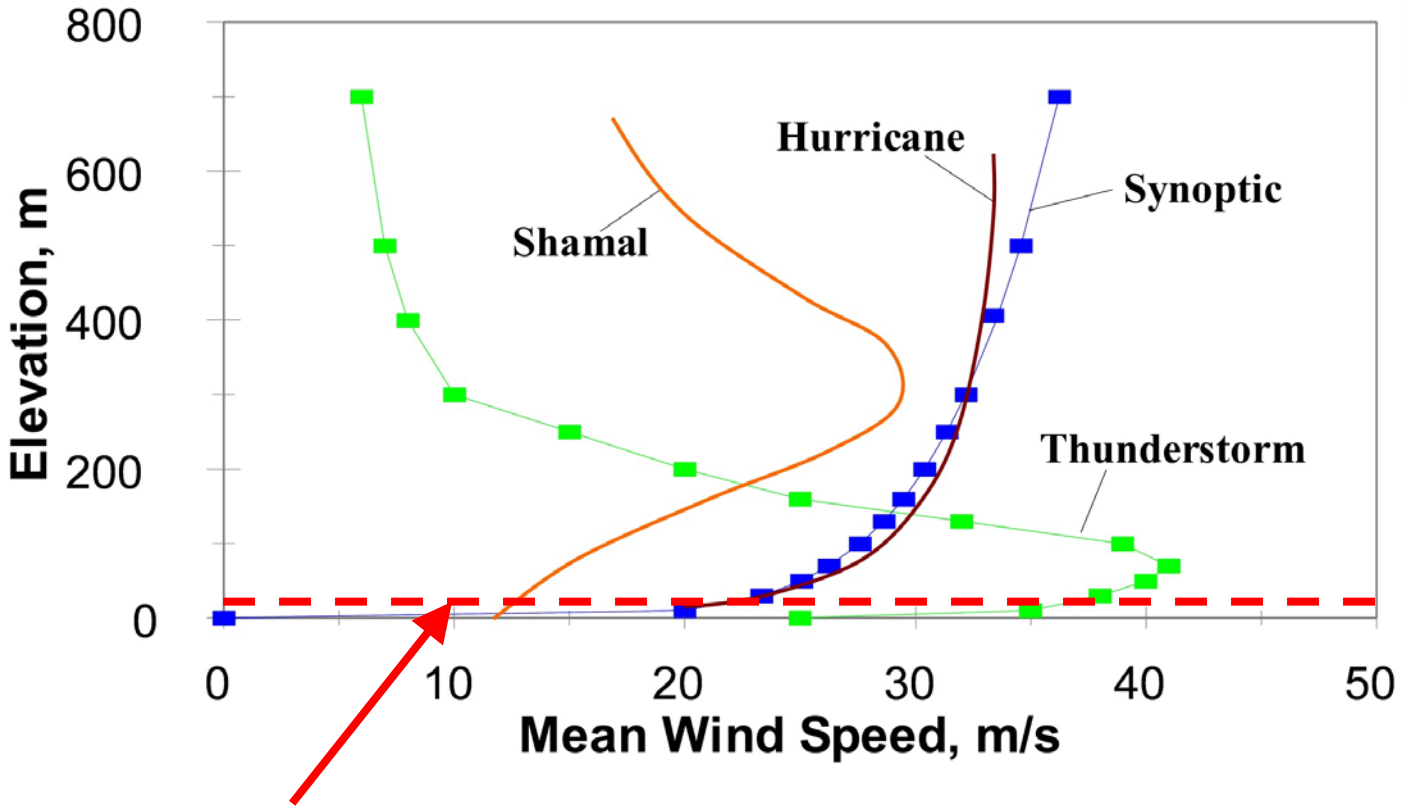
Sometimes the Met Data is Lacking

Burj Khalifa – 820 m tall

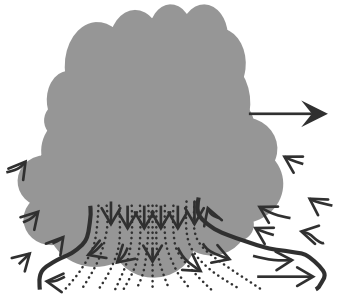
Wind measured at ground level is not good enough



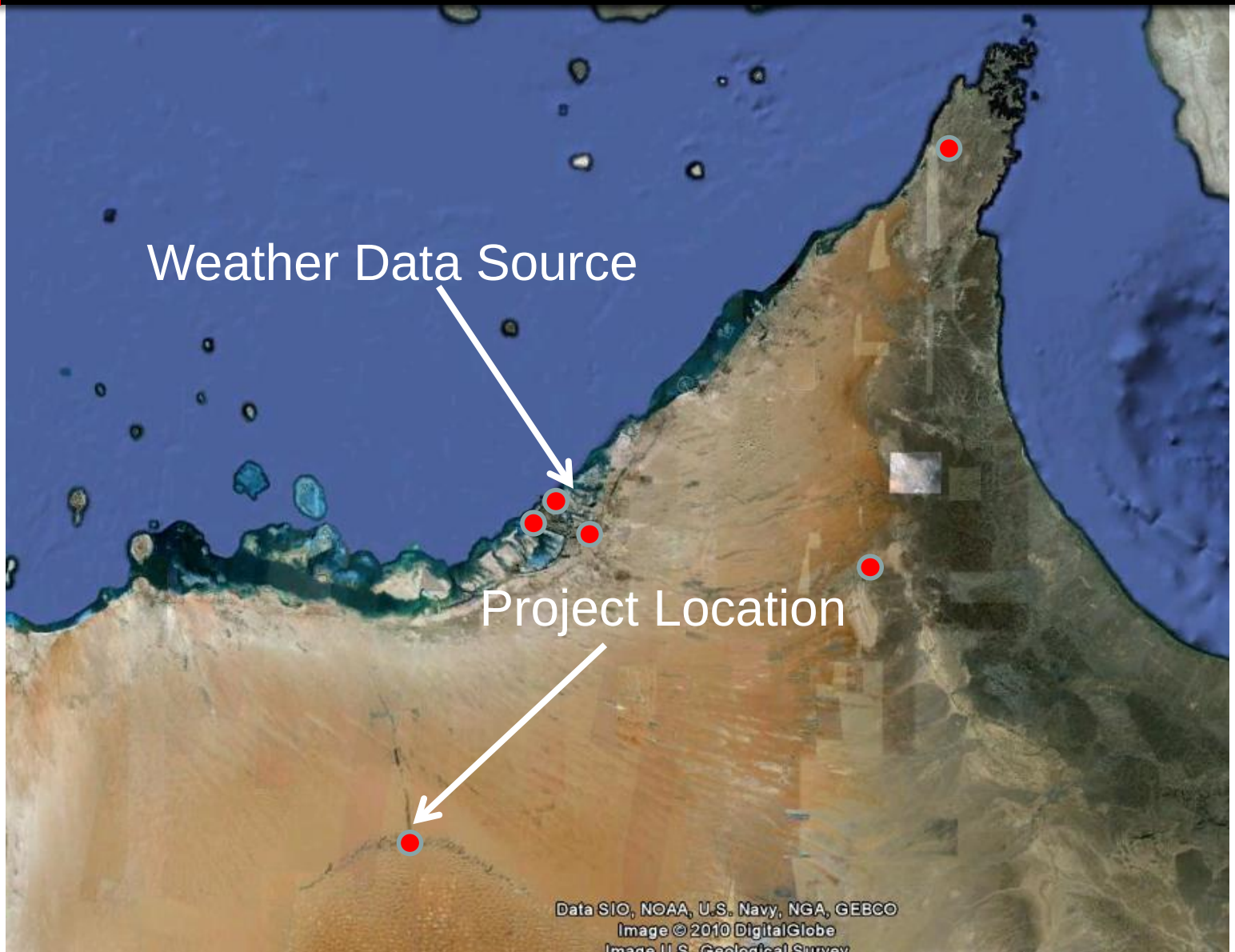
Wind Profile



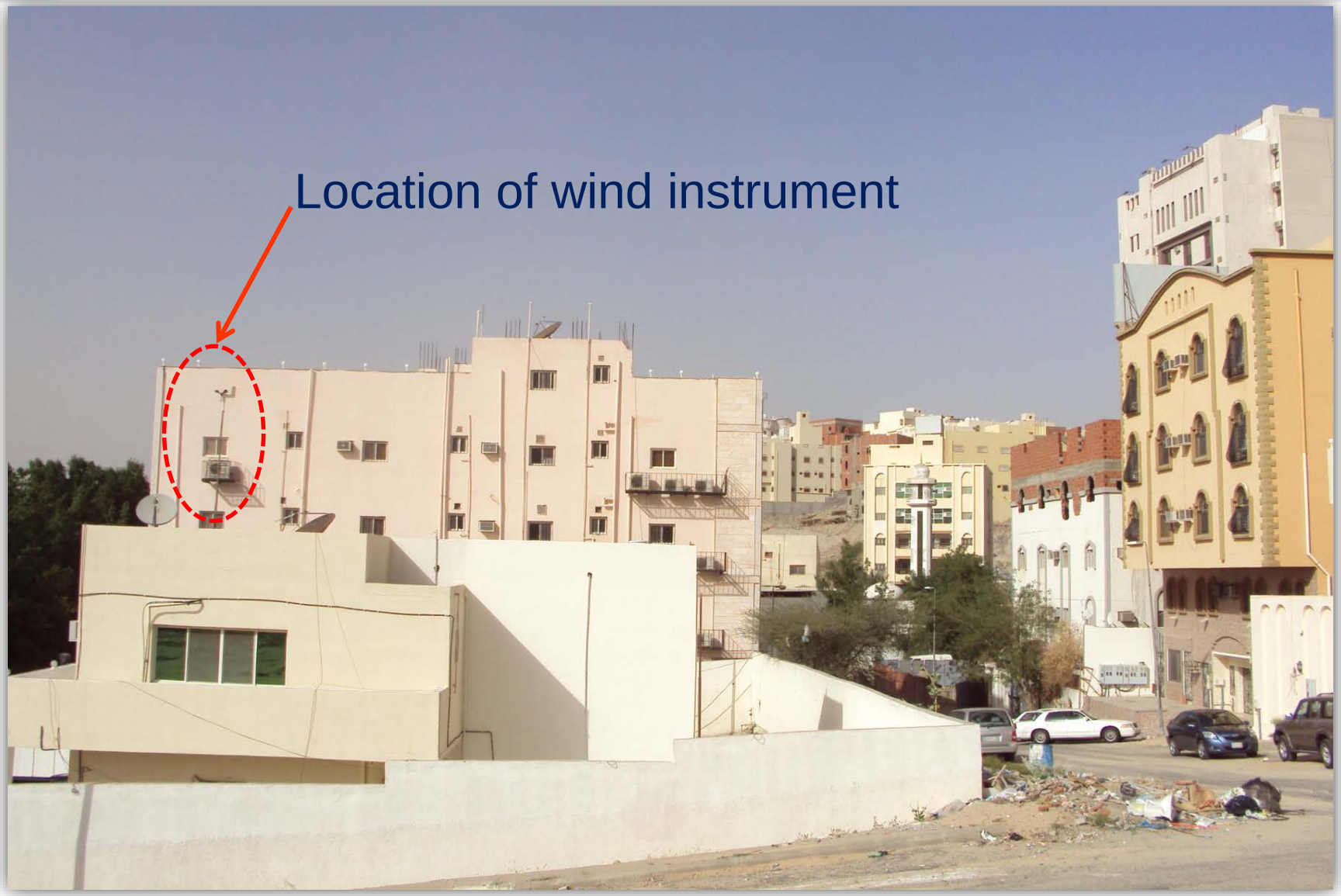
Historical wind data recorded at surface level



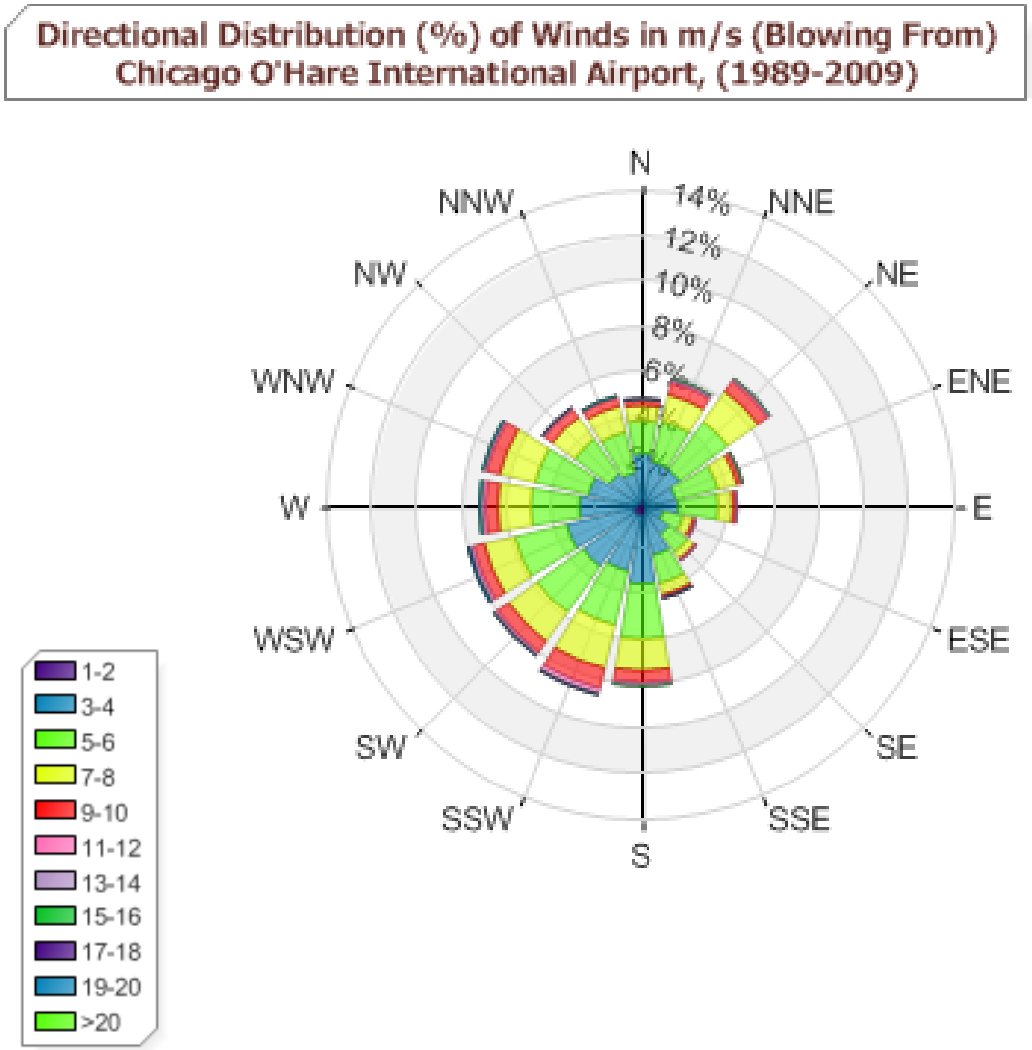
Sometimes the Met Data Is Not Valid

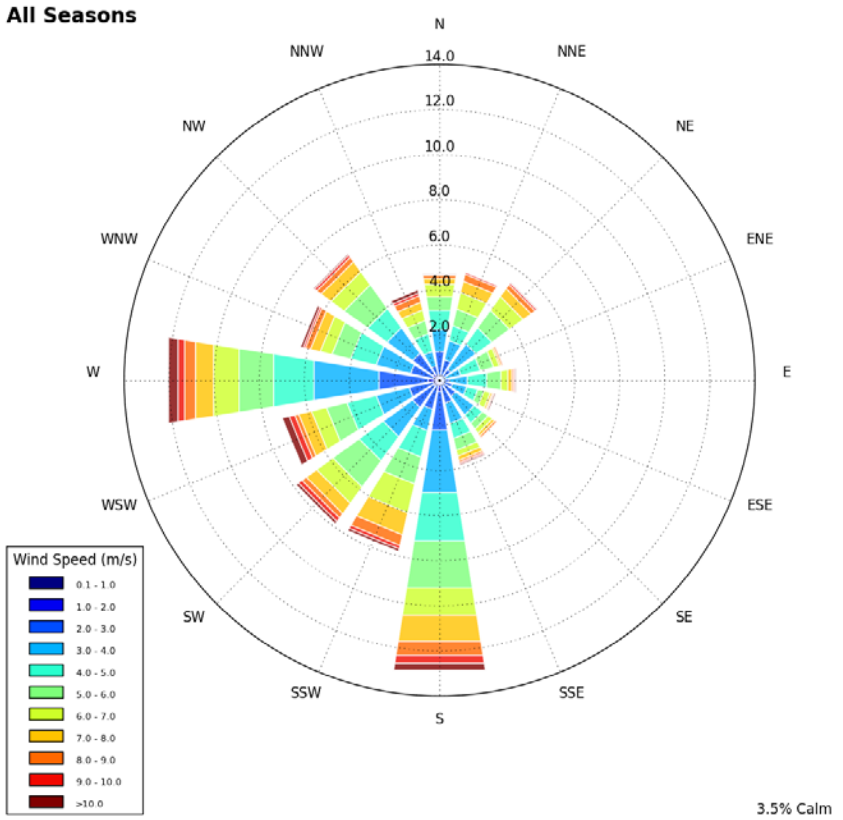


Sometimes the Met Data is Just Wrong



Sometimes the Data Filtering Affects Parameters





So what can we do? … Adjust the met Data

Statistical

Dependent upon measurement data availability / quality and includes: multi-site and auto-correlations; Weibull models; monte-carlo simulations; etc.

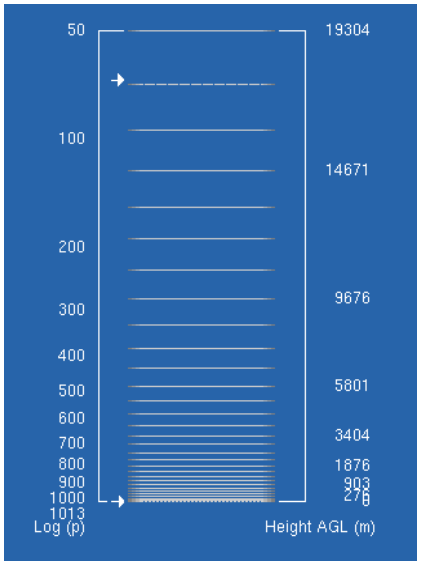
Diagnostic

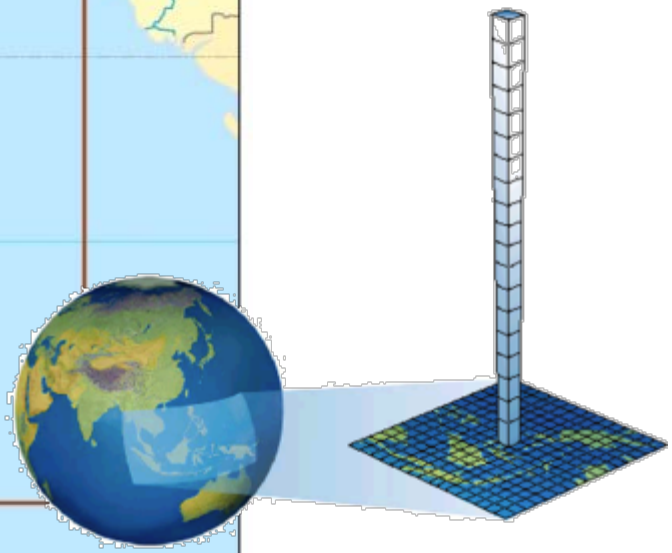
Dependent upon measurement data and involves 2-D or 3-D interpolation with limited physics where each hour is treated independently.

Prognostic

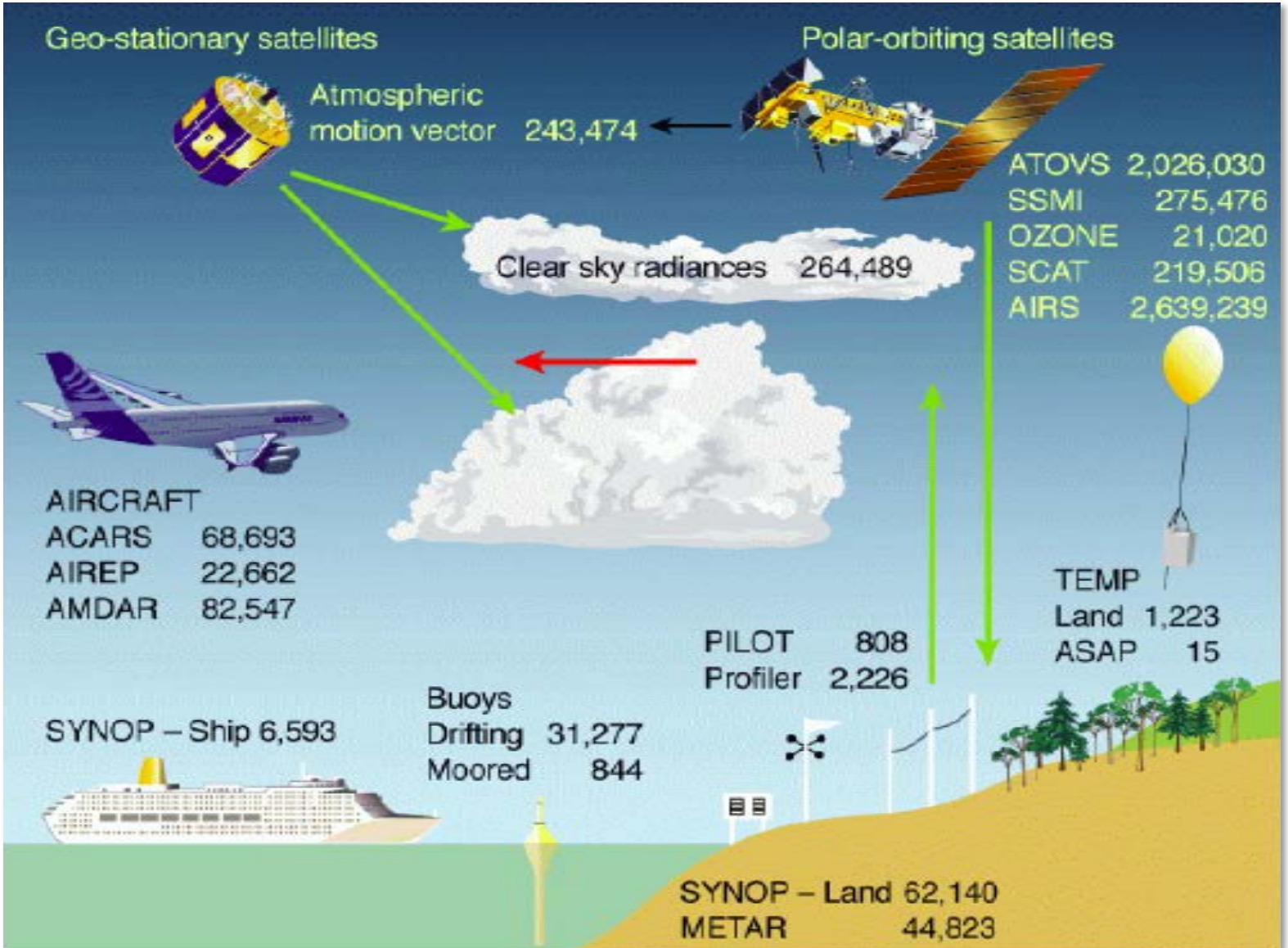
4-D weather simulation models that simulate the physics of atmospheric motions from first principals.

Prognostic modeling – nested grid paradigm



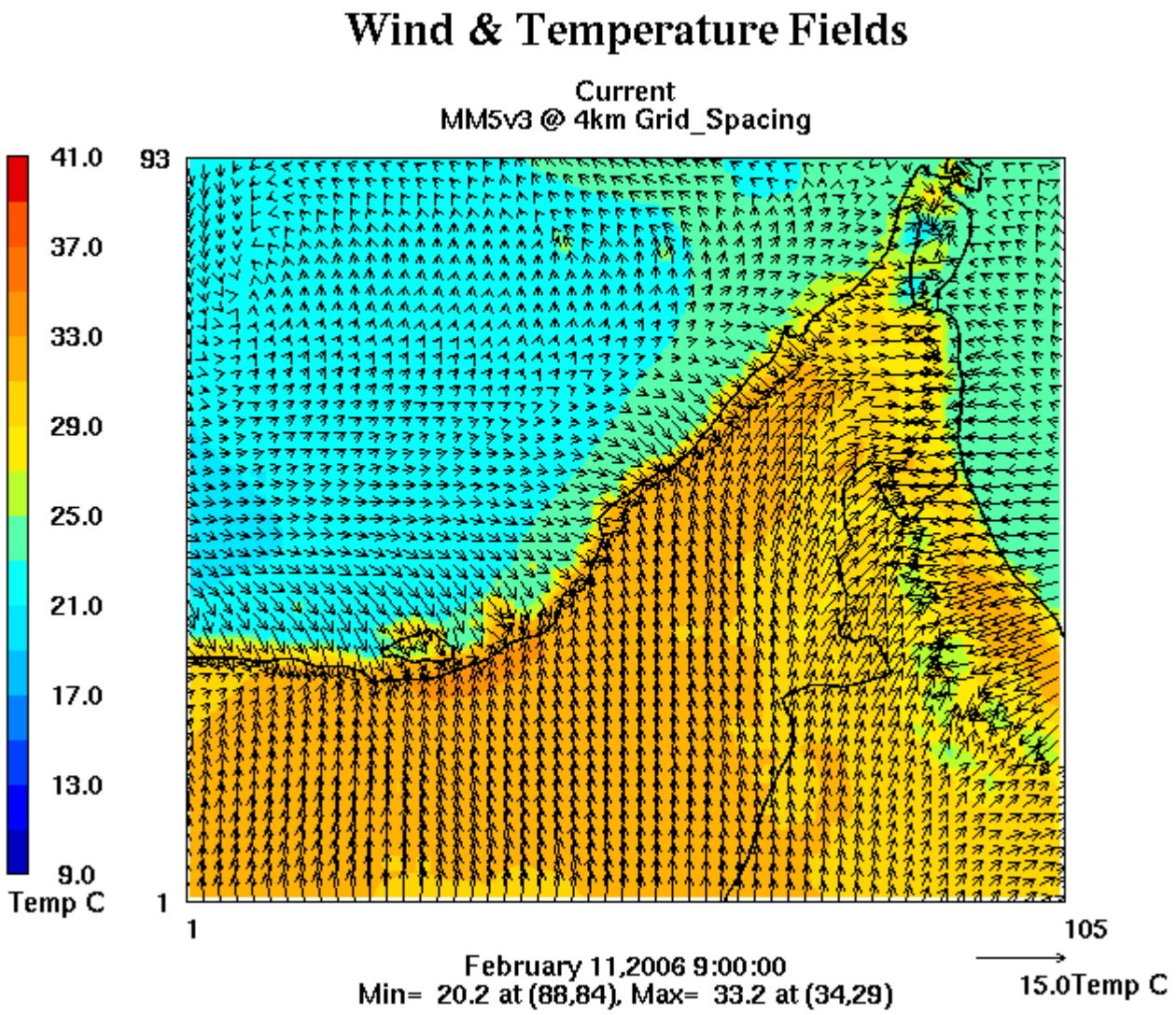


Prognostic modeling – nested grid paradigm



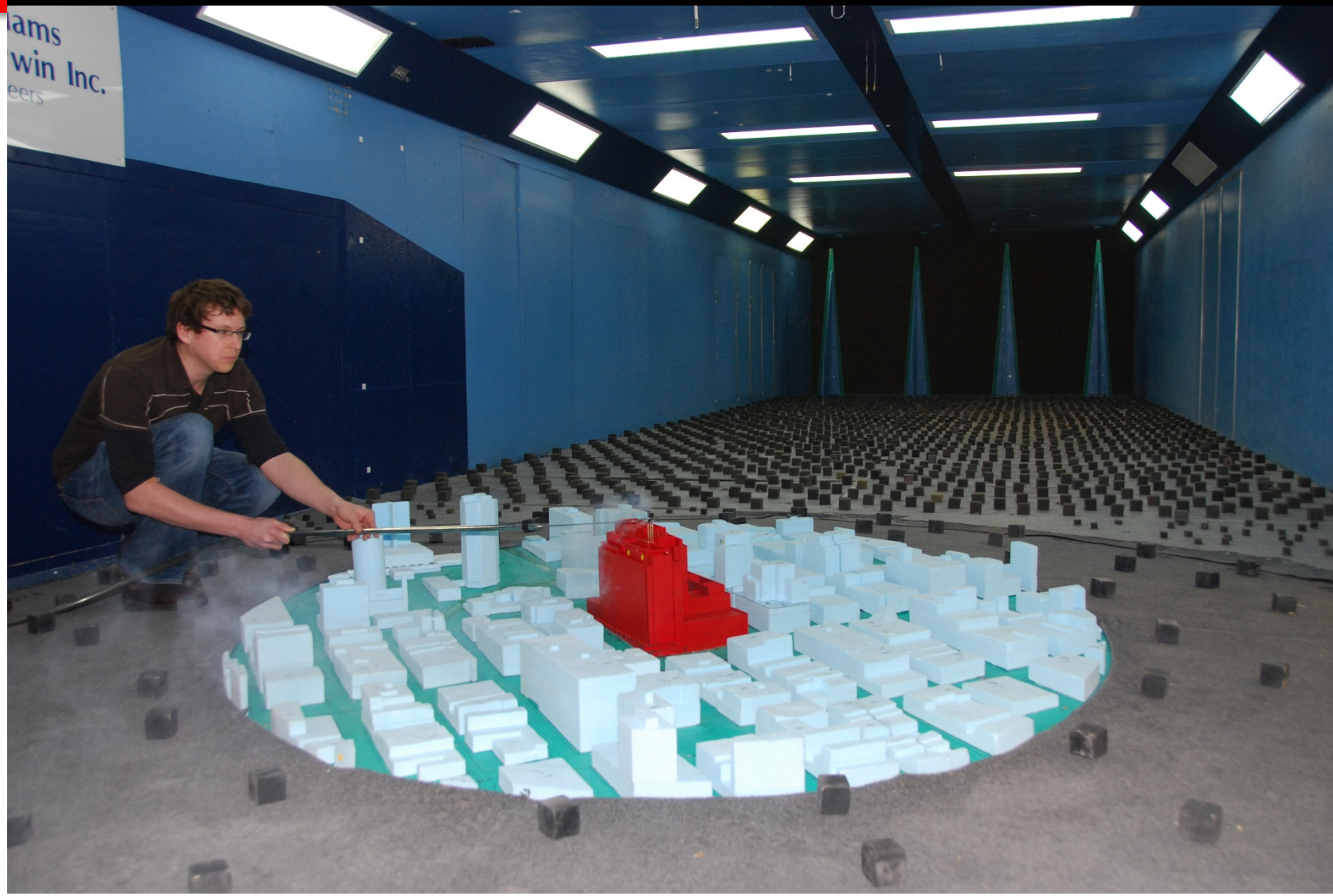
Study of UAE

- Client needed higher fidelity of meteorological data
- Prognostic model used to replicate local conditions.
- Modeling also used to assess planned land use changes and climate change.

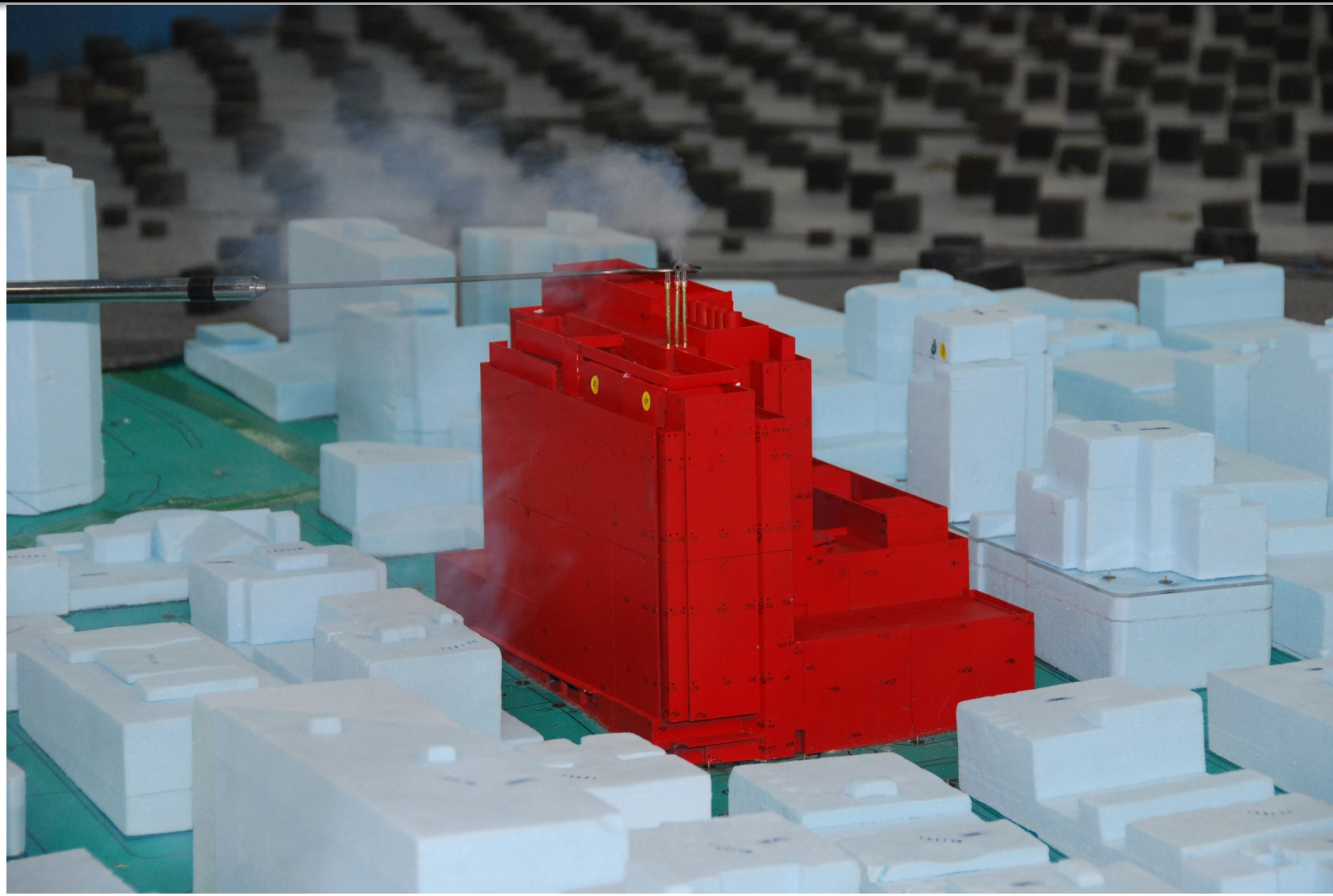


Wind Tunnel

Wind Tunnel

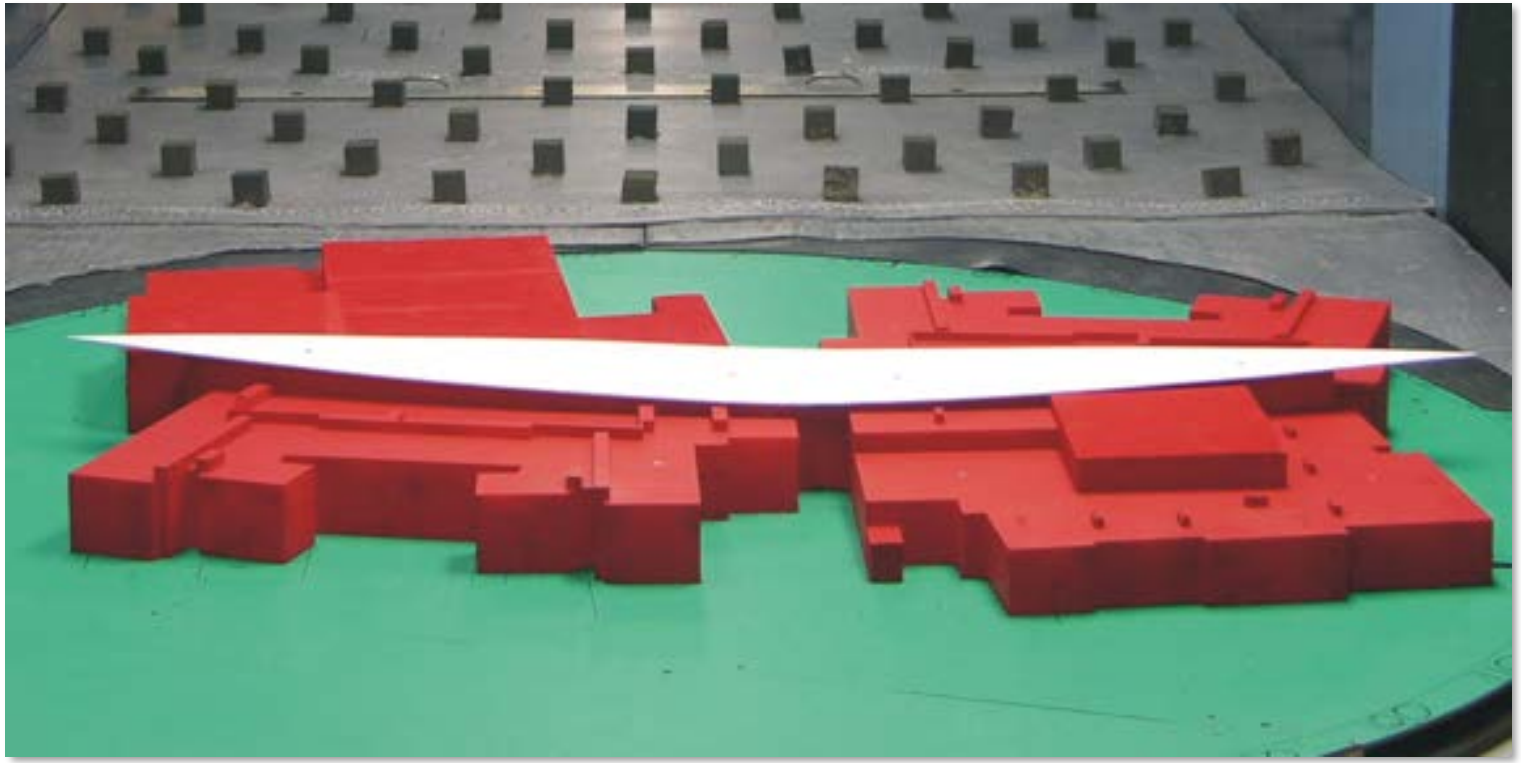


Wind Tunnel

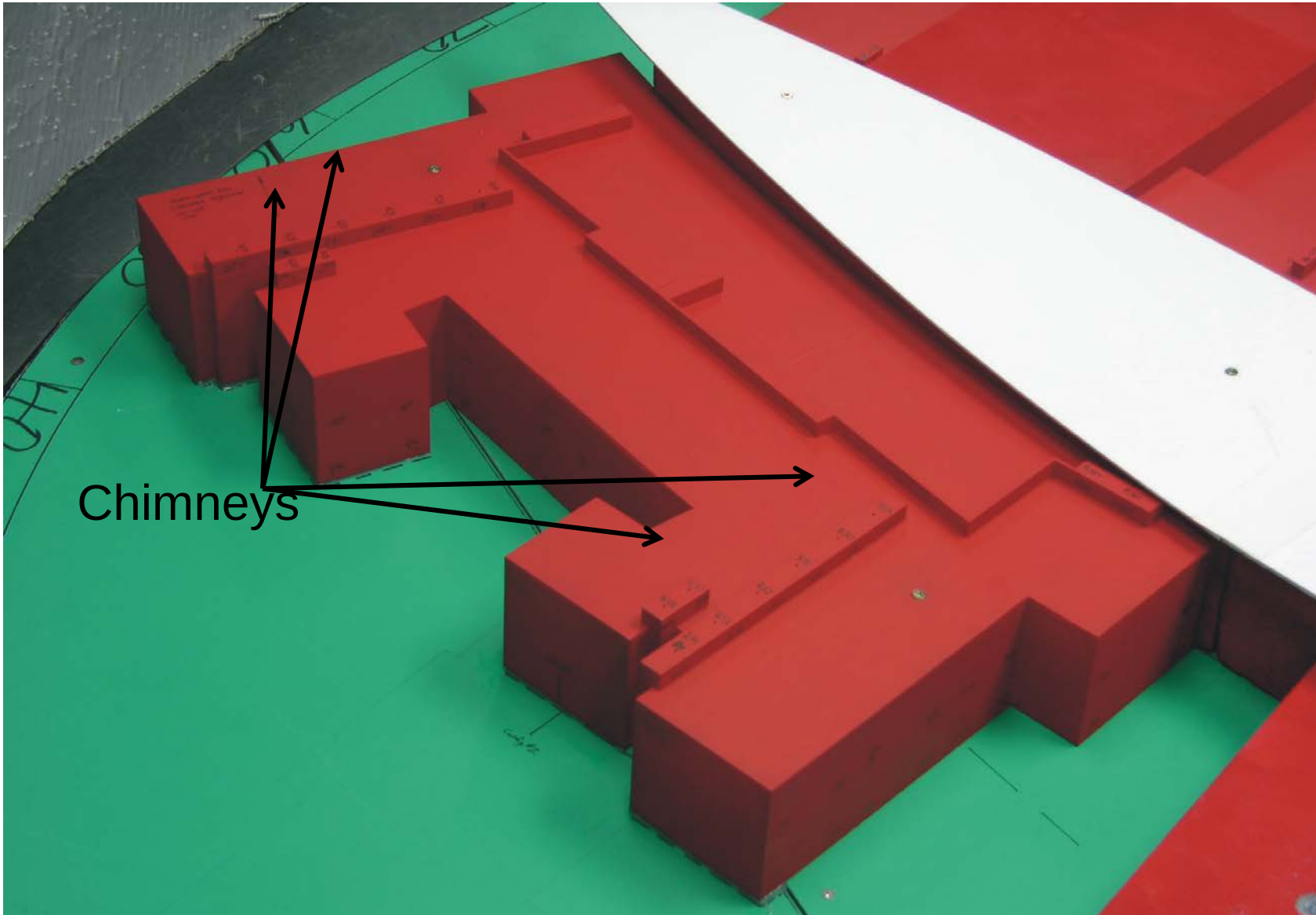


Wind Tunnel

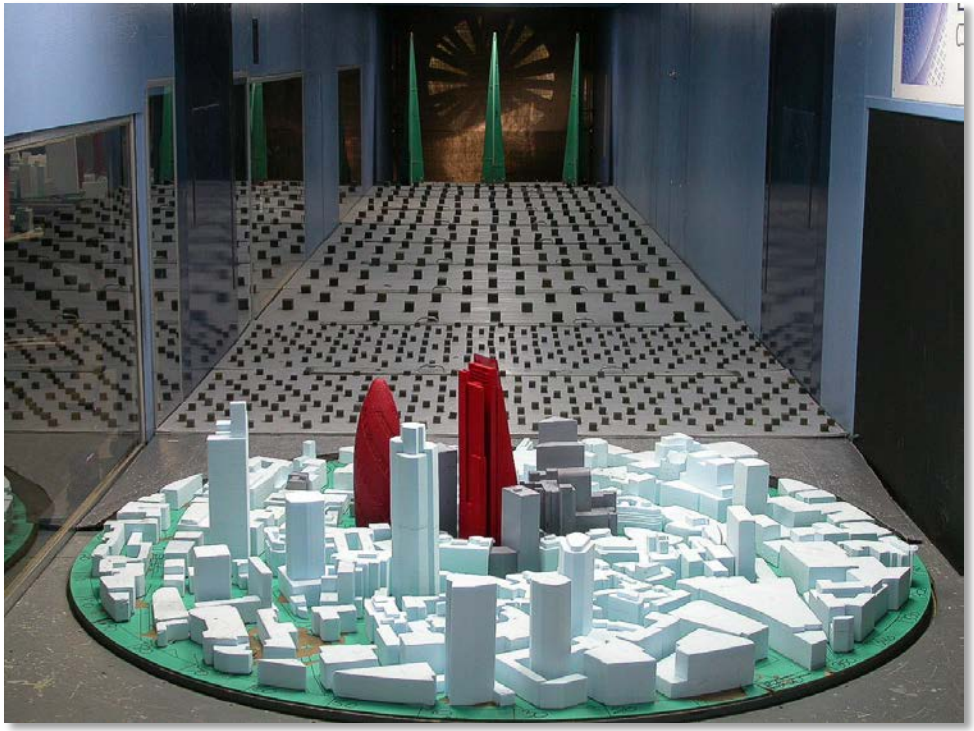
Wind tunnel model



Windtunnel Measurements



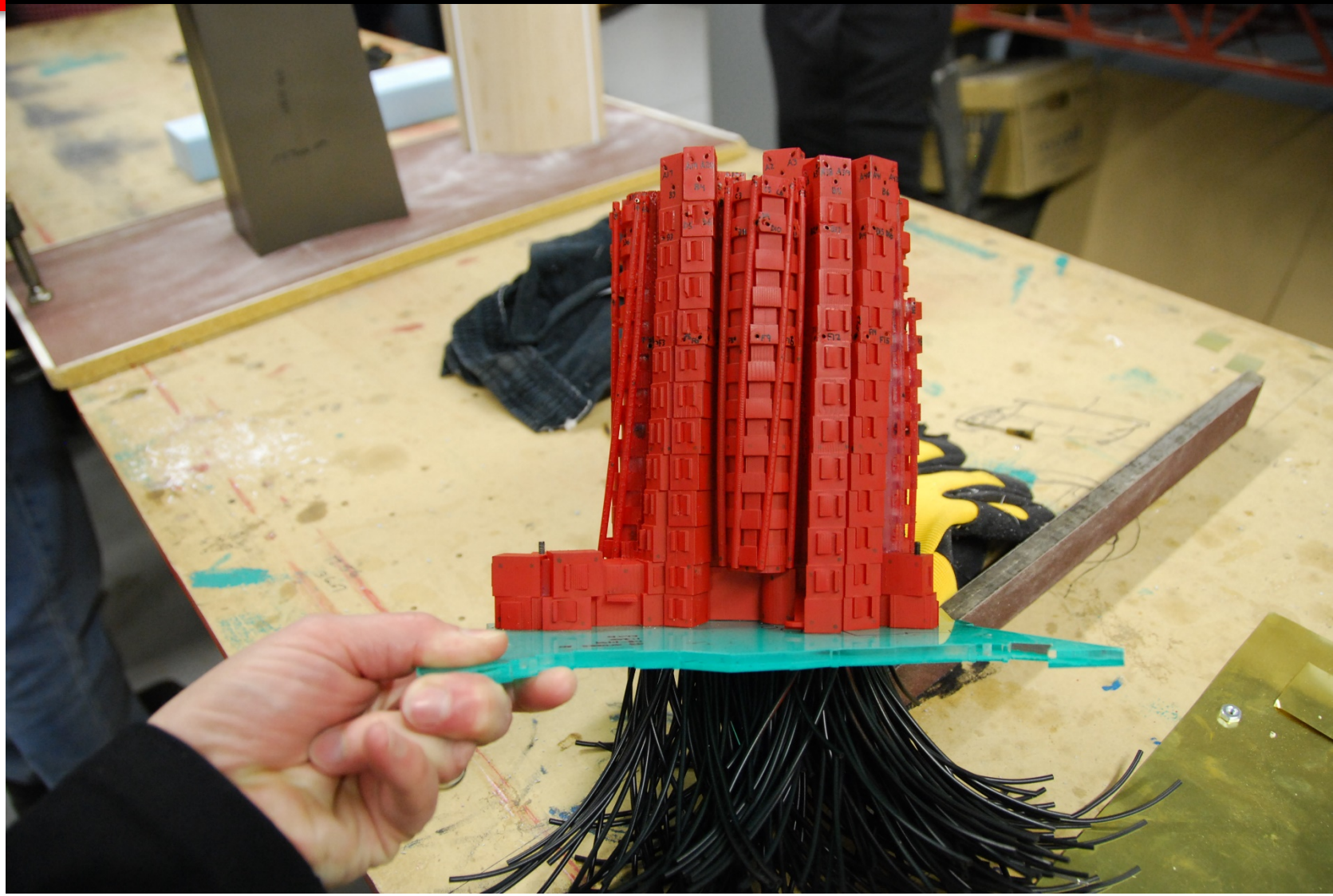
Urban situation easy to check



Models for the Leadenhall Building that include Swiss Re, previously modeled + site condition at base of buildings

Model Shop

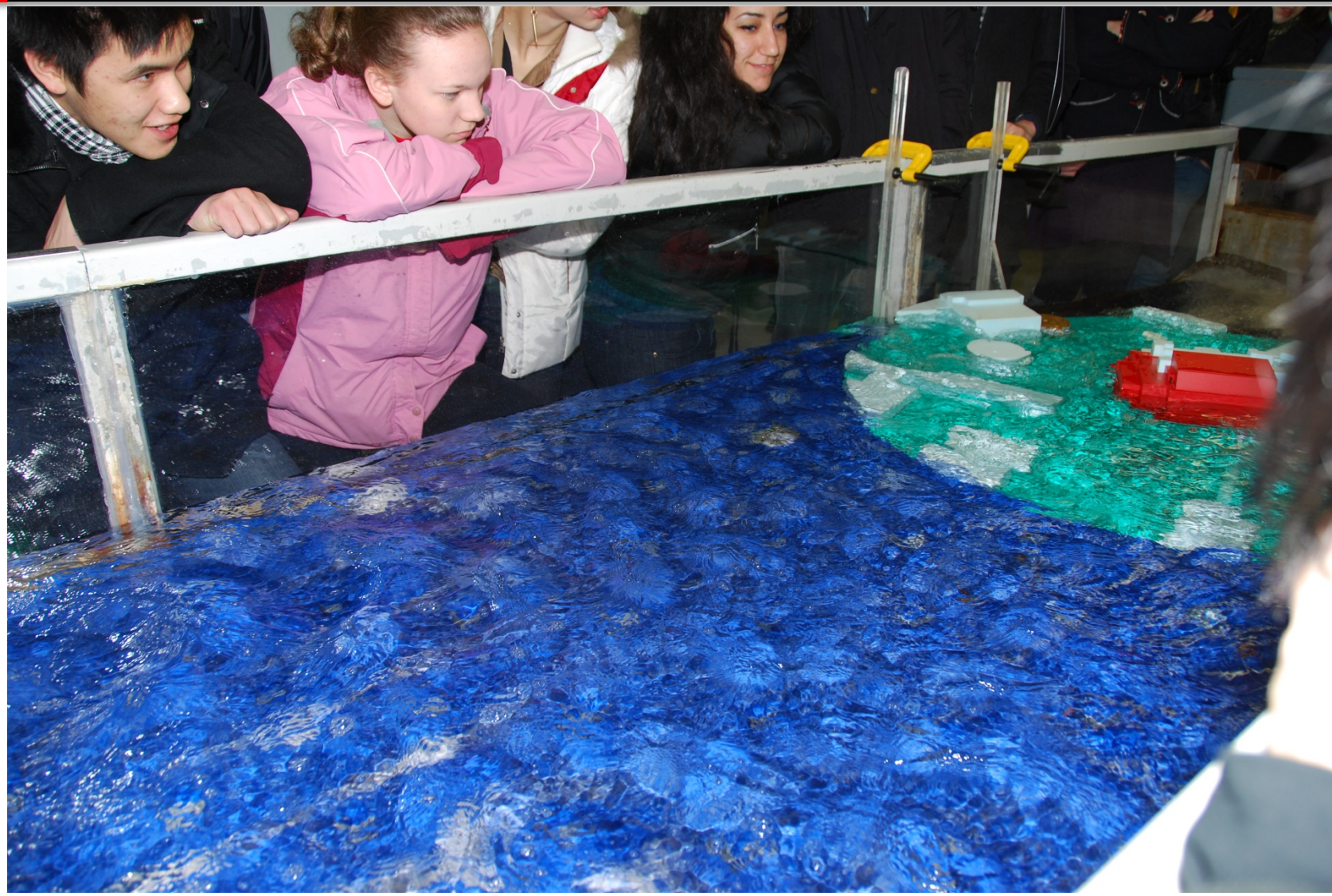
Specially constructed models



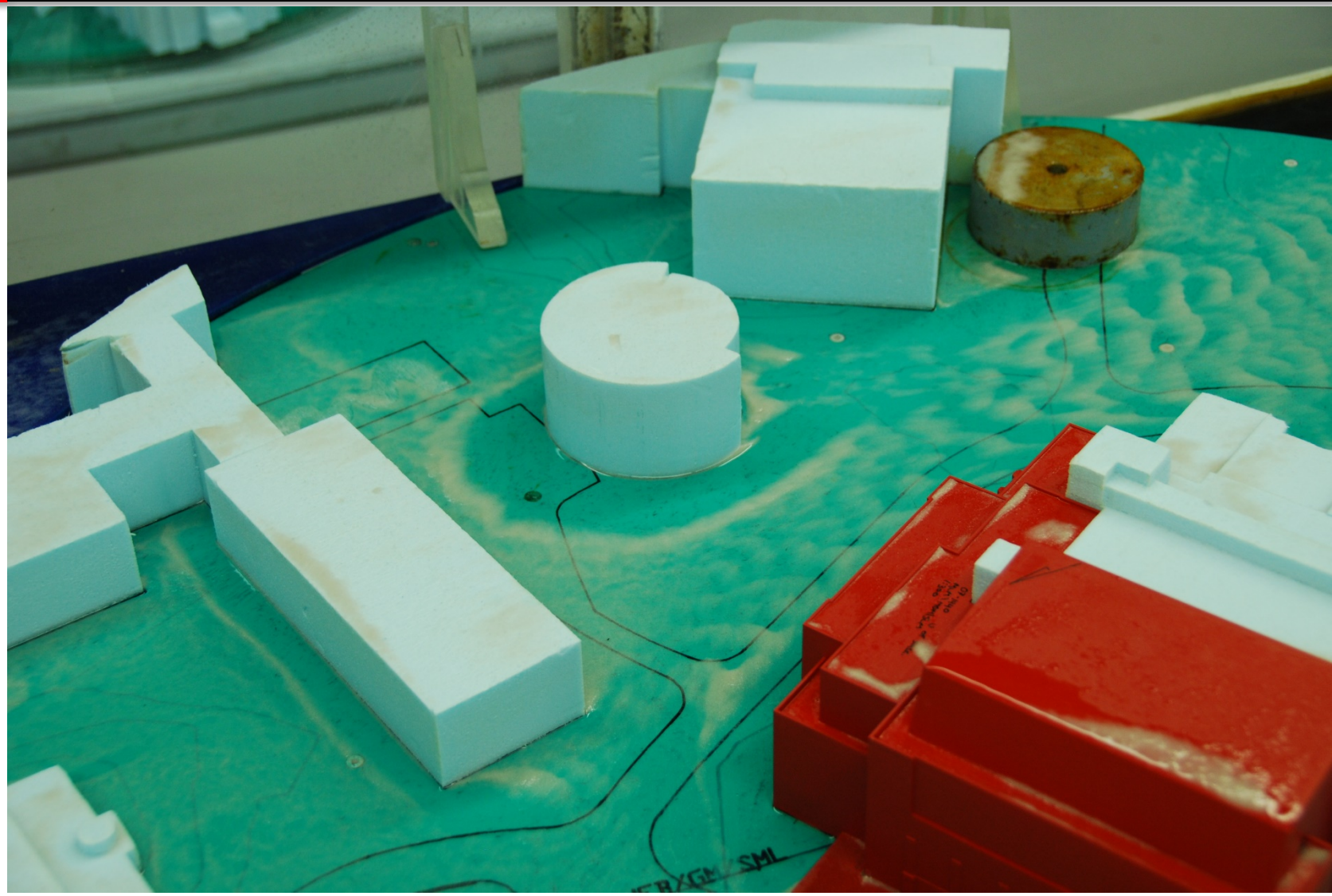
World class facility

Water Flume

Water Flume



Water Flume



Seismic Testing

For earthquake prone areas, large scale models are put on a shake table to simulate and test structures.