OAA 2030™

A partner program of the
AIA+2030 Professional Series™

PREPARE FOR THE NEW ENERGY FUTURE™

Accentuate the Positive: Climate Responsive Design

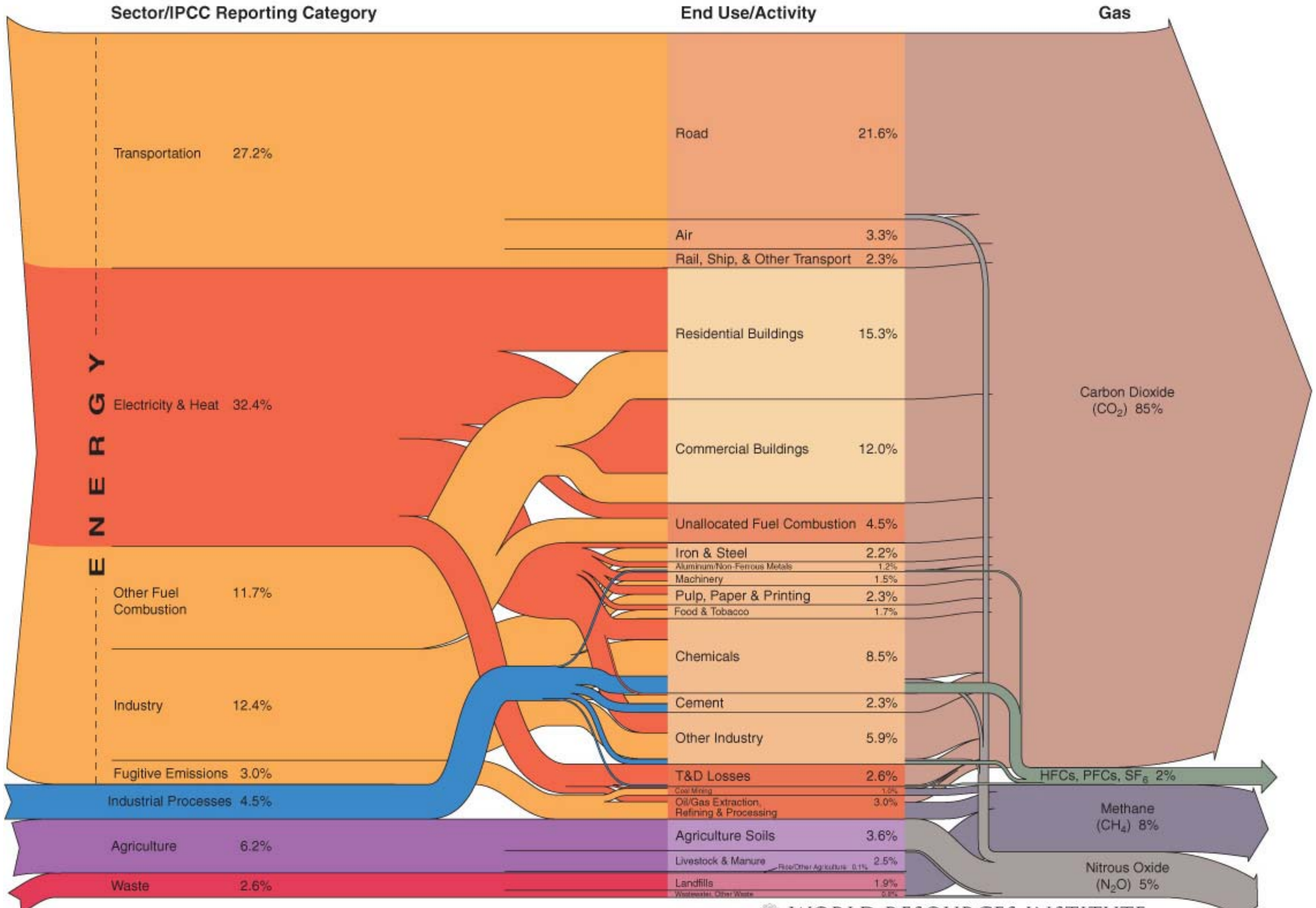
Developed in cooperation with: aia seattle architecture 2030 Sponsored By: RAIC | IRAC Architecture Canada

The Global Warming Pie....

These values look at Secondary **Energy Use** by Sector in Canada (2006)
(*energy used by the final consumer i.e. operating energy*)

Emissions and their Sources

U.S. GHG Emissions Flow Chart



WORLD RESOURCES INSTITUTE

CONNECTICUT

ARIZONA

NEW MEXICO

FLORIDA

Opportunities to Work With and Harvest Climate

Roughly….

The Sun = Free Heat, Light, Cooling & Ventilation

The Wind = Free Ventilation & Cooling

Rain & Snow = Free Water & Cooling

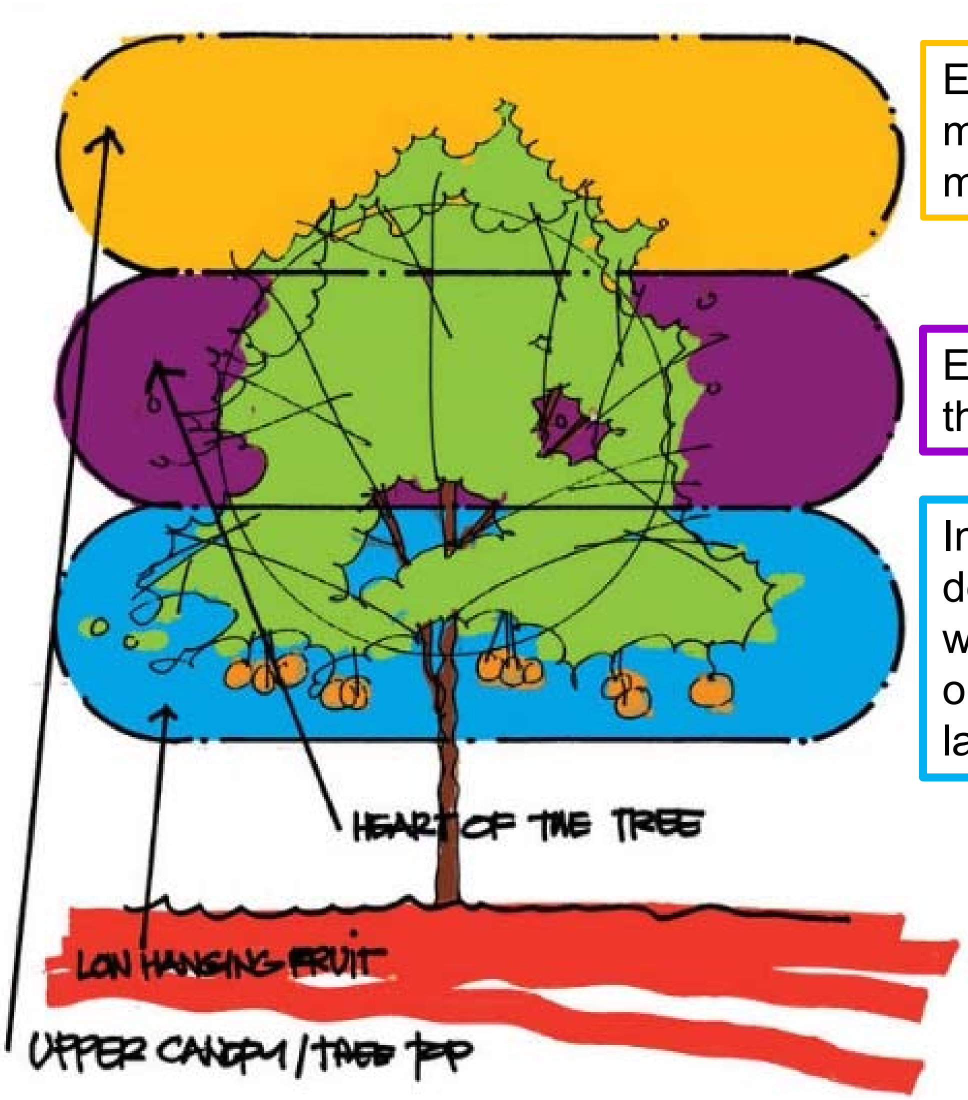
There is lots that can and must be done at the OUTSET of a project with respect to the Climate, Building Siting and Orientation that can HELP to reduce energy.

If not done you will spend a lot of time and energy working to correct these bad decisions.

Good decisions at the start can be built upon ….

Bad decisions at the start need to be corrected ….

Low Hanging Fruit



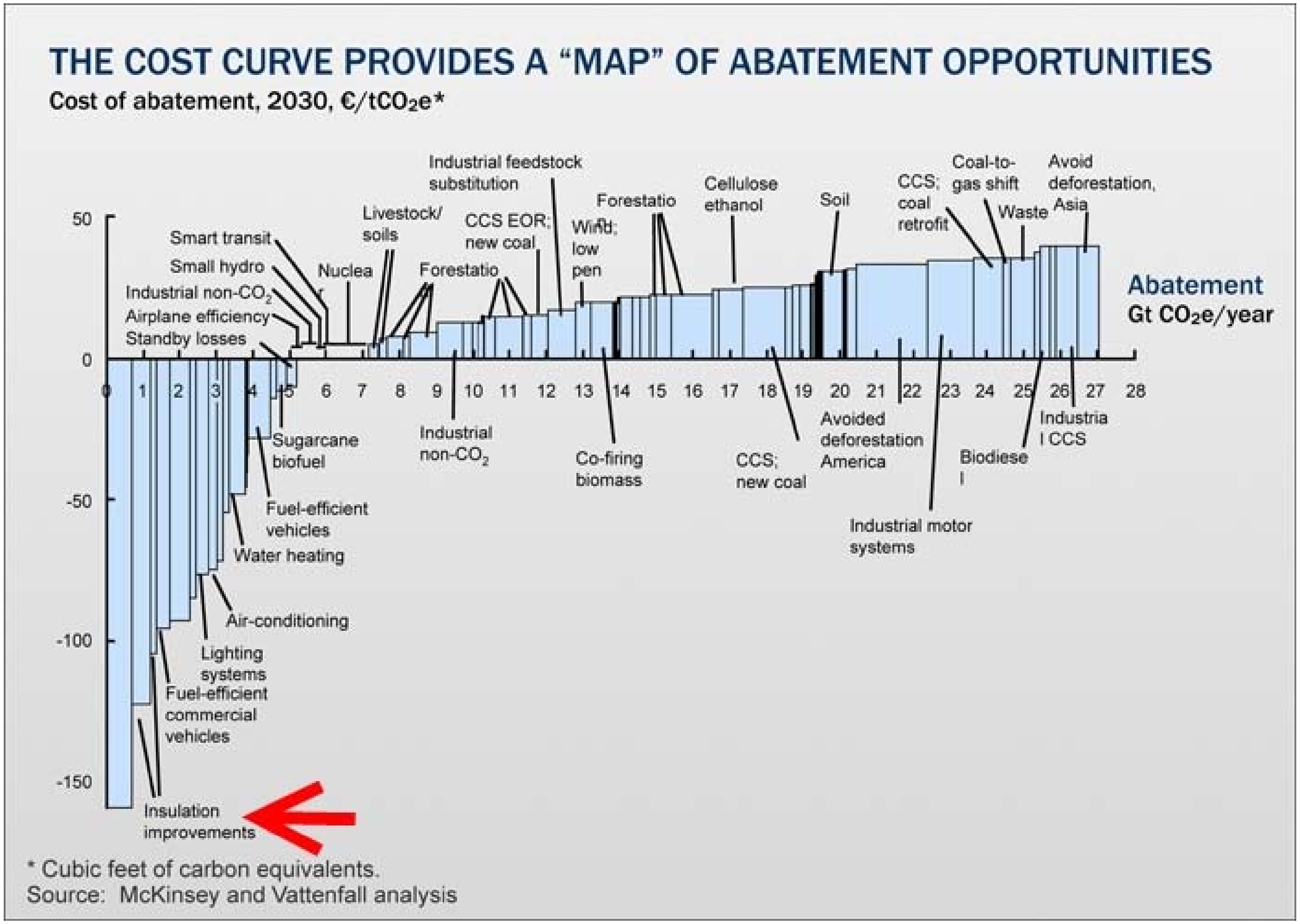
Expensive systems such as PV, micro wind turbines, various mechanical and electrical equipment

Extra insulation, better windows, thermal mass, shading devices.

Initial site and climate based design decisions that really cost nothing but will benefit the project: climate, orientation, adjacencies, massing, landscaping

www.amdgarchitects.com

McKinsey Report identifies some basic good building moves that can save energy



THE COST CURVE PROVIDES A “MAP” OF ABATEMENT OPPORTUNITIES

Cost of abatement, 2030, €/tCO₂e*

* Cubic feet of carbon equivalents.

Source: McKinsey and Vattenfall analysis

Energy vs Greenhouse Gas Emissions

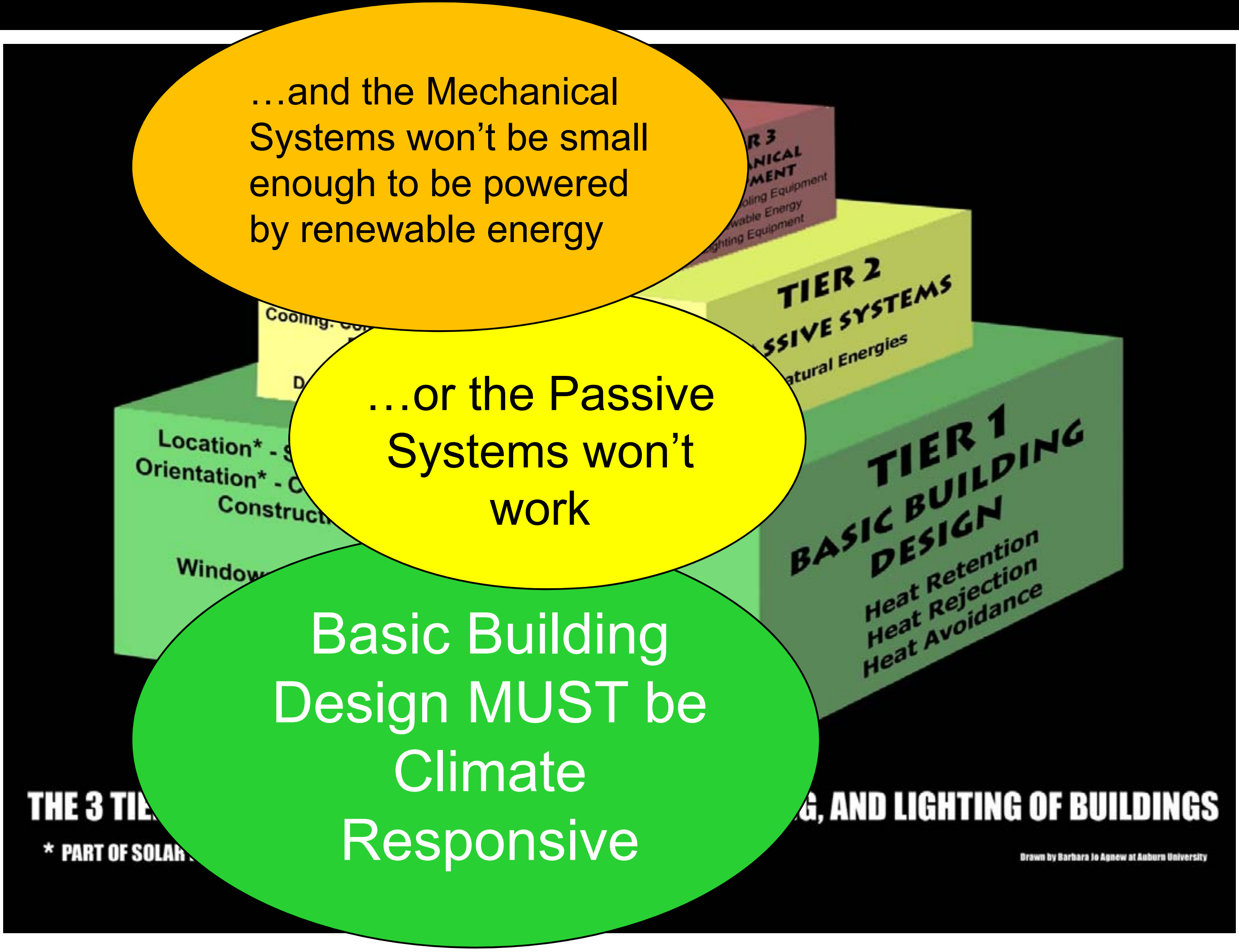
In BUILDINGS, for the sake of argument

ENERGY CONSUMPTION = GHG EMISSIONS

BUILDING ENERGY IS COMPRISED OF

EMBODIED ENERGY
+
OPERATING ENERGY

Carbon Reduction: The Tier Approach



…and the Mechanical Systems won't be small enough to be powered by renewable energy

…or the Passive Systems won't work

Basic Building Design MUST be Climate Responsive

Image: Norbert Lechner, "Heating, Cooling, Lighting"

The Importance of Understanding Building Physics

A detailed understanding of the physics is not essential

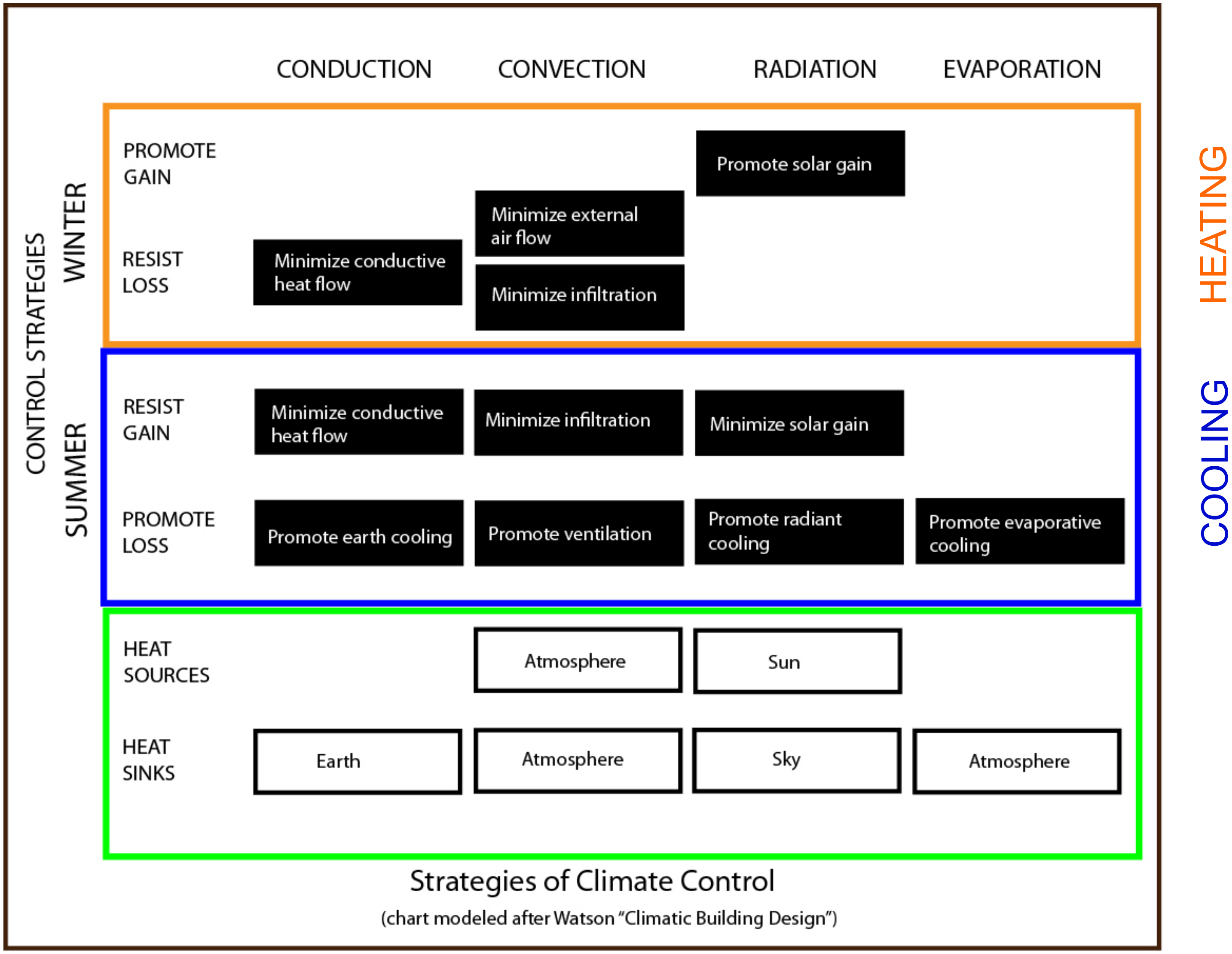
BUT! It is important to understand limitations

There is no free energy

Some forms of energy are weak

Stack effect for natural ventilation

Begin with Passive Strategies for Climate Control to Reduce Energy Requirements



CONTROL STRATEGIES

		CONDUCTION	CONVECTION	RADIATION	EVAPORATION	
WINTER	PROMOTE GAIN			Promote solar gain		HEATING
	RESIST LOSS	Minimize conductive heat flow	Minimize external air flow Minimize infiltration			
SUMMER	RESIST GAIN	Minimize conductive heat flow	Minimize infiltration	Minimize solar gain		COOLING
	PROMOTE LOSS	Promote earth cooling	Promote ventilation	Promote radiant cooling	Promote evaporative cooling	
	HEAT SOURCES		Atmosphere	Sun		
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere	

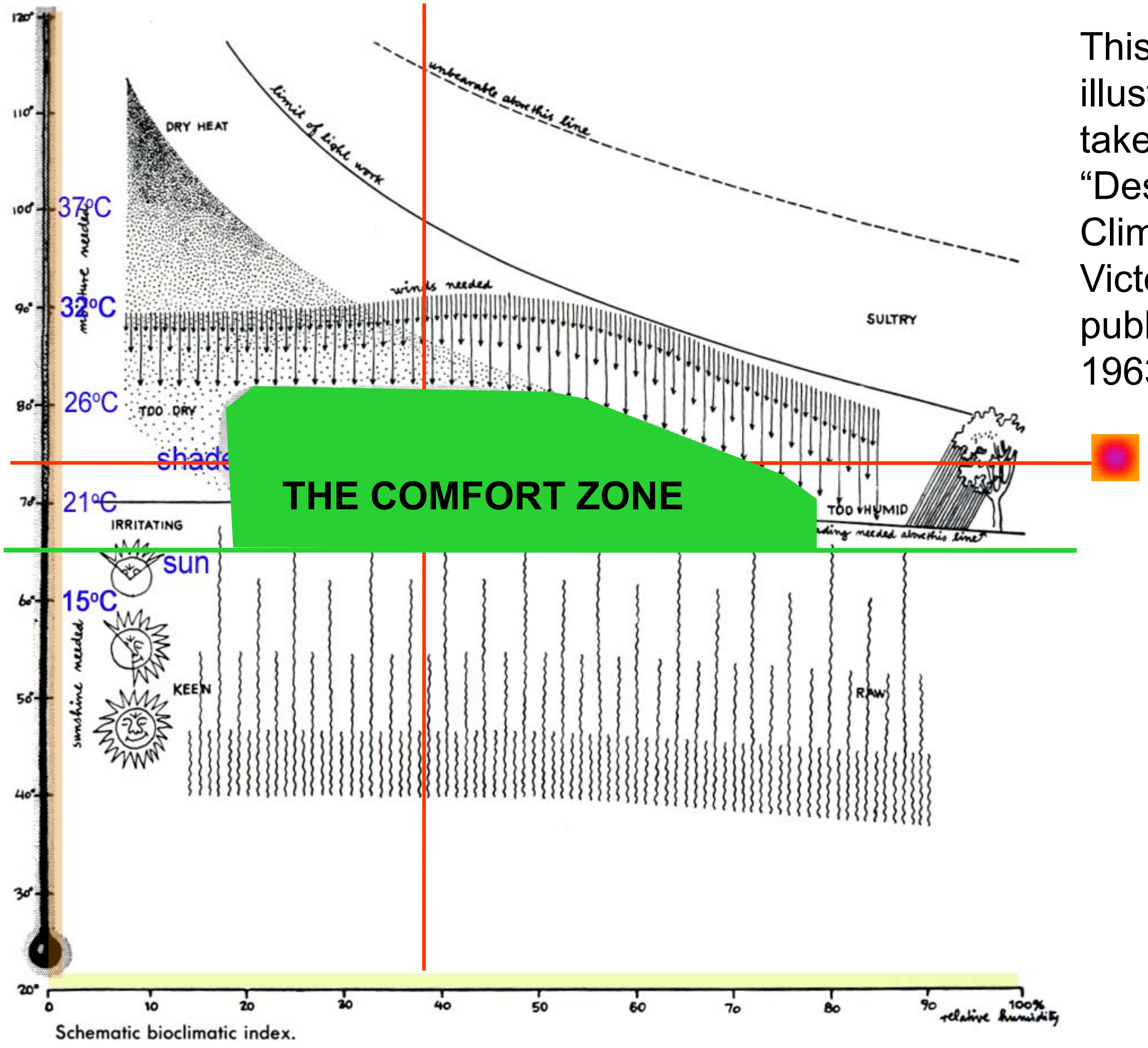
Strategies of Climate Control

(chart modeled after Watson "Climatic Building Design")

Climate as the Starting Point
for a
Climate Responsive Design

Designing to the **Comfort Zone** vs. Comfort Point:

REDUCING OPERATING ENERGY



This famous illustration is taken from "Design with Climate", by Victor Olgyay, published in 1963.

Passive Bio-climatic Design: COMFORT ZONE

IDEALLY comfort expectations may have to be reassessed to allow for the wider “zone” that is characteristic of buildings that are not exclusively controlled via mechanical systems.

Creation of new **“buffer spaces”** to make a hierarchy of comfort levels within buildings.

Require **higher occupant involvement** to adjust the building to modify the temperature and air flow.

North American Bio-climatic Design:

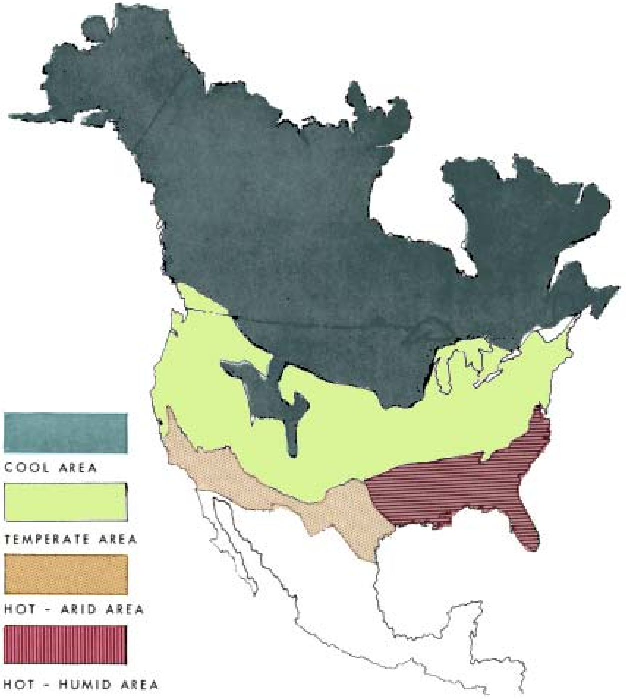
Design must first acknowledge regional, local and microclimate impacts on the building and site.

COLD

TEMPERATE

HOT-ARID

HOT-HUMID

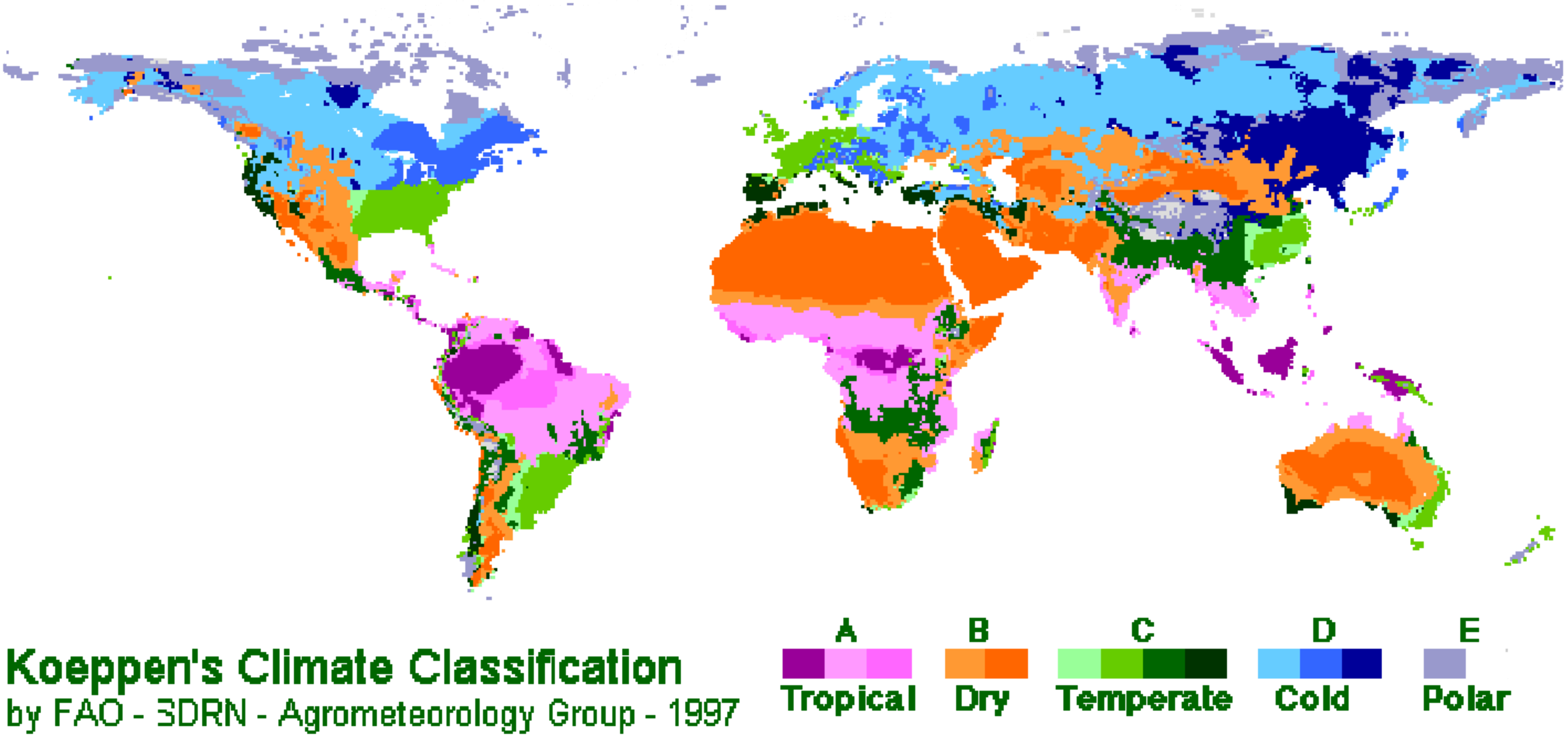


11. Regional climate zones of the North American continent.

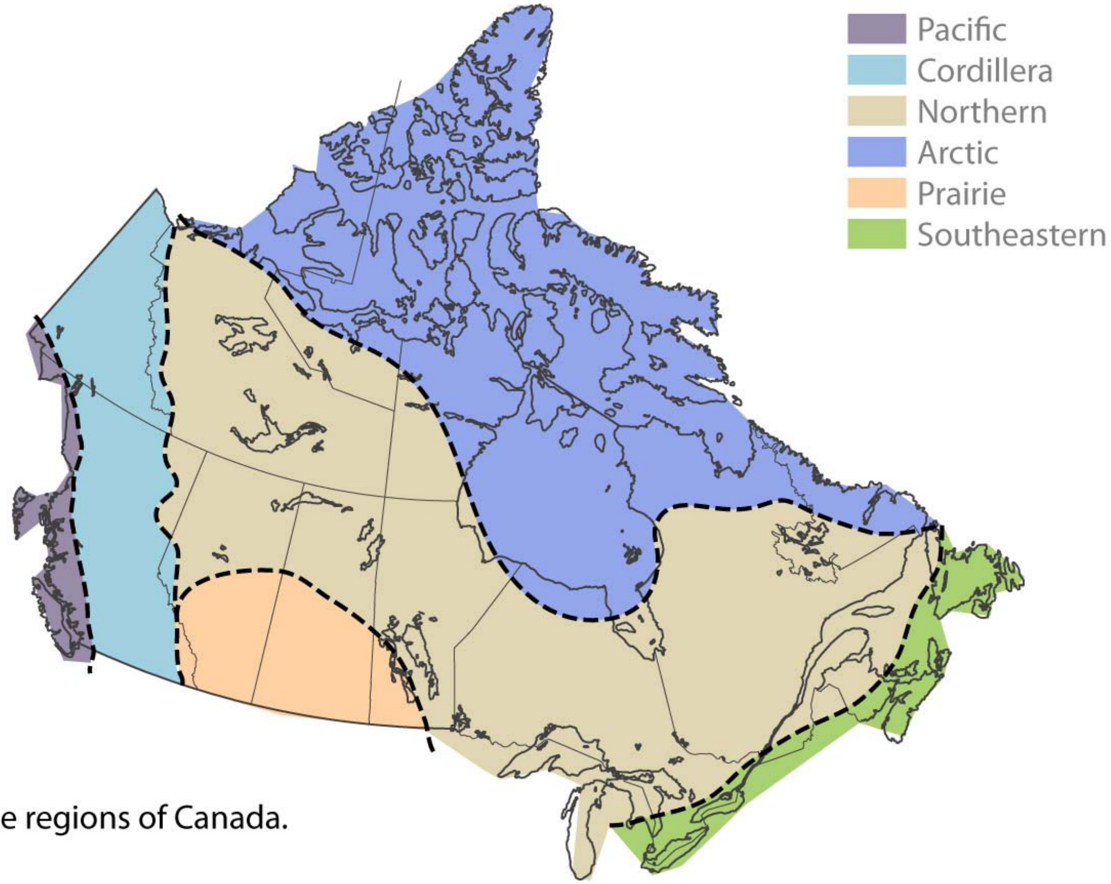
Image: 1963 “Design With Climate”, Victor Olgyay.

Global Bio-climatic Design:

Design must first acknowledge regional, local and microclimate impacts on the building and site.



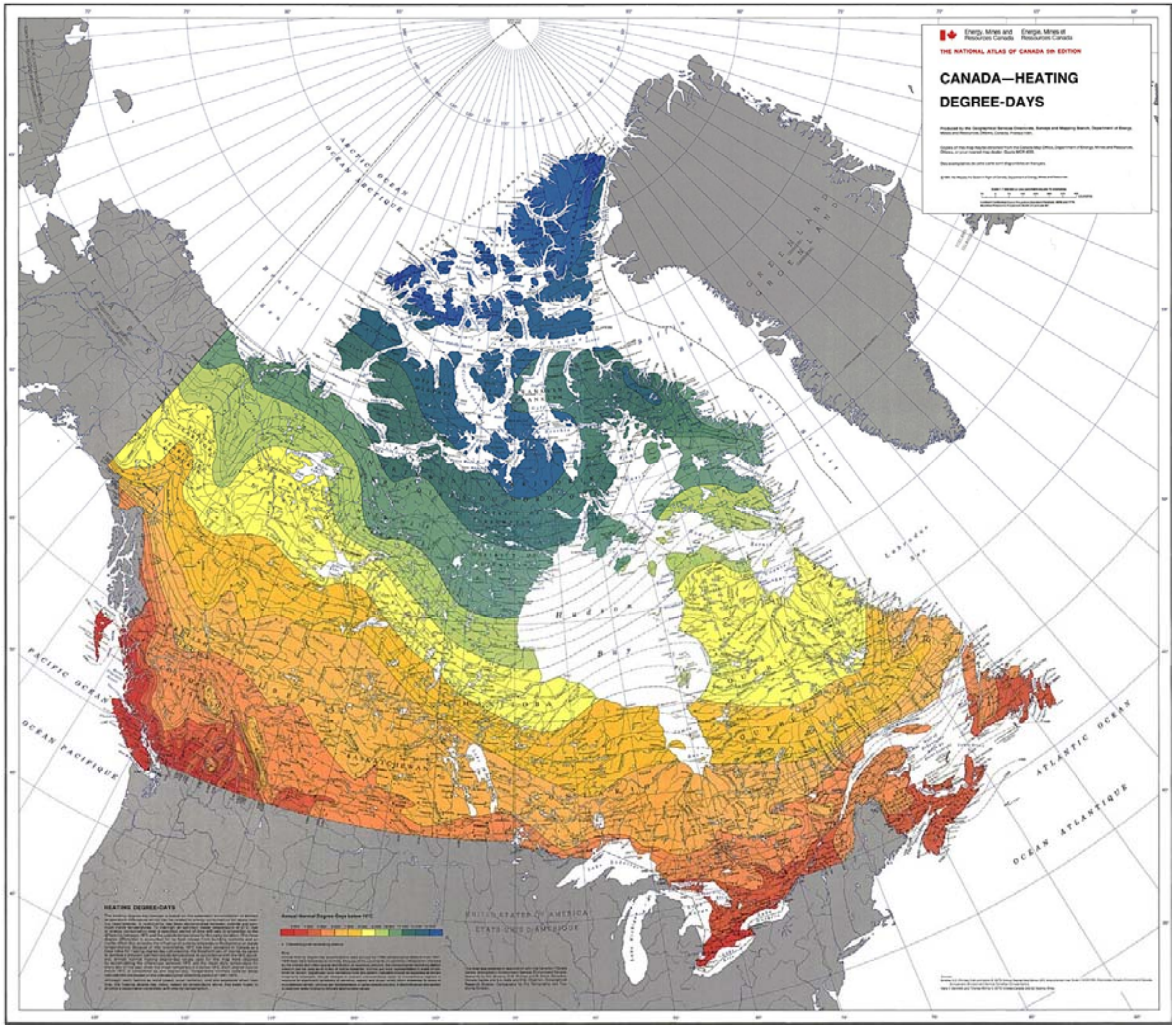
The climate regions of Canada



Climate regions of Canada.

Even within Canada, there exist variations in climate, enough to require very different envelope design practices and regulations. This mostly concerns insulation and water penetration, as well as humidity concerns.

Heating and Cooling Degree Days

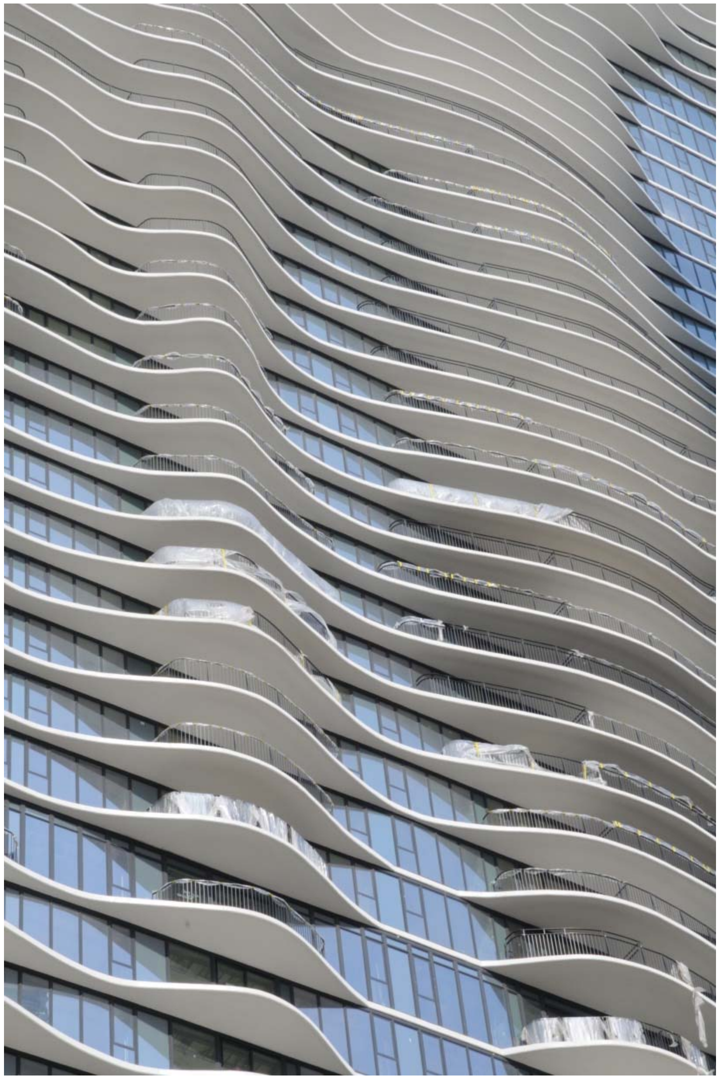


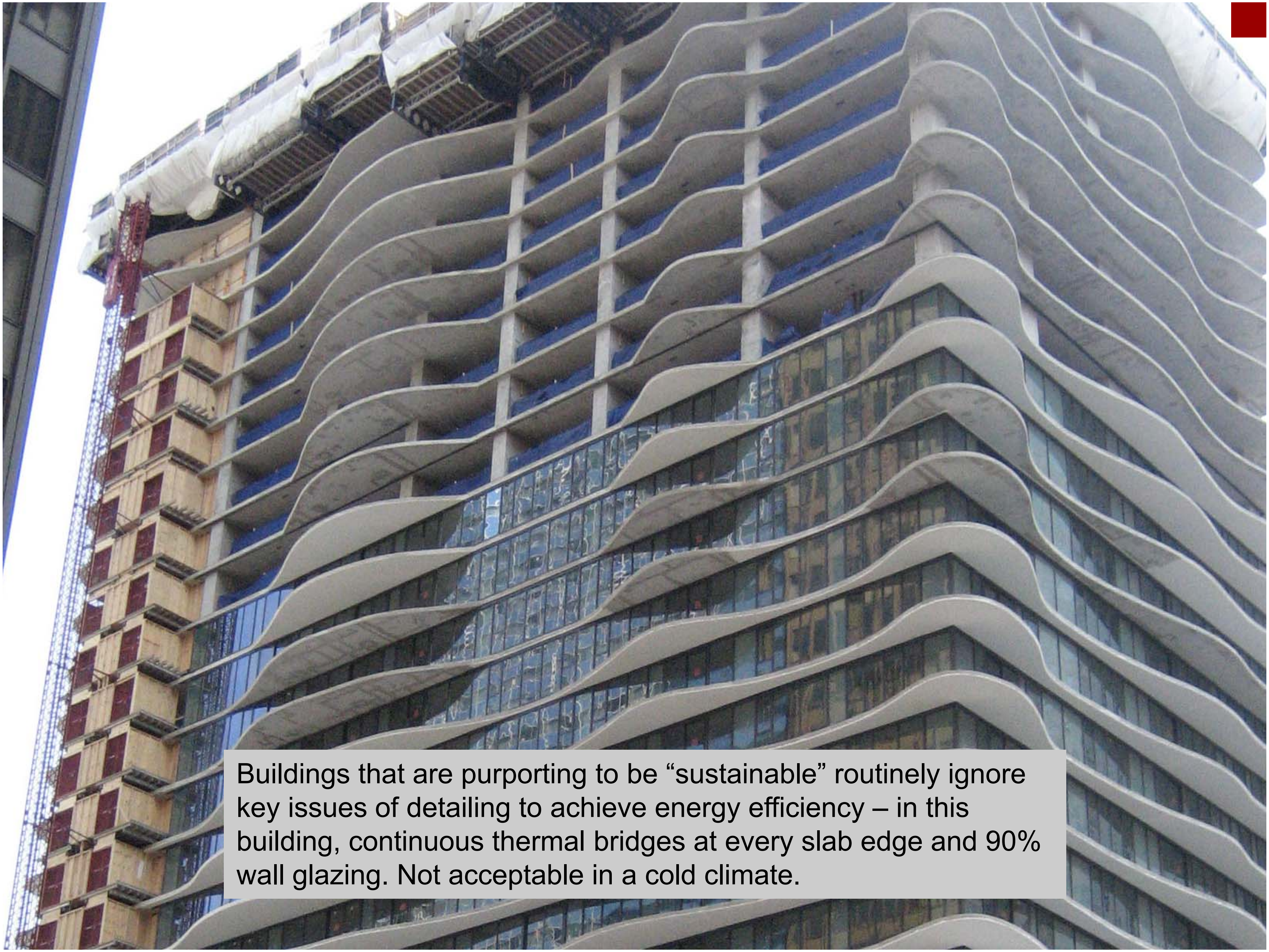
This map shows the annual sum of heating degree days (an indicator of building heating needs). Data for period 1941 to 1970.

Determine if the climate is *heating* or *cooling* dominated …this will set out your **primary strategy**.

The Controversial “Cover” of Greensource Magazine

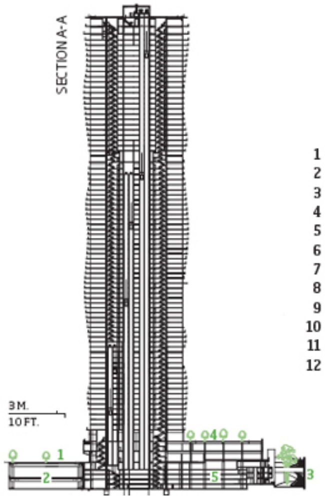
A “sustainable” Chicago residential skyscraper – going for LEED



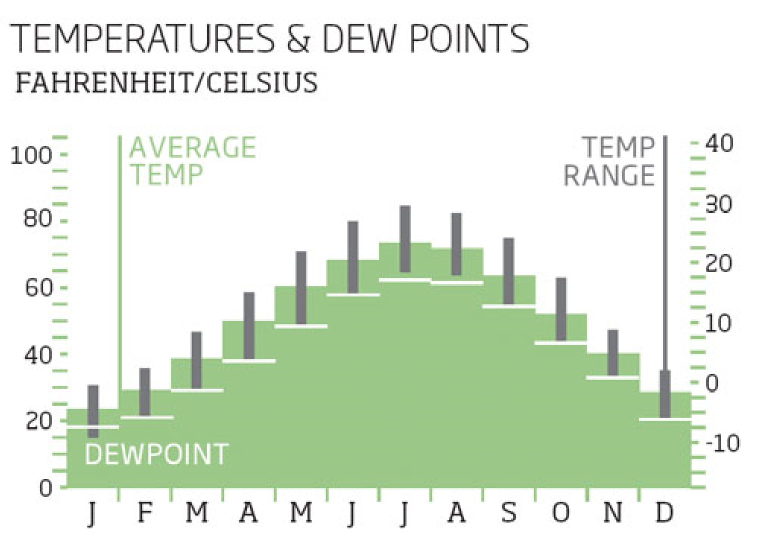


Buildings that are purporting to be “sustainable” routinely ignore key issues of detailing to achieve energy efficiency – in this building, continuous thermal bridges at every slab edge and 90% wall glazing. Not acceptable in a cold climate.

Chicago Climate Data



1 Upper Columbus Drive
2 Lower Columbus Drive
3 Stair to Harbor Park
4 Roof garden
5 Parking
6 Living/dining room
7 Den
8 Kitchen
9 Bedroom
10 Master bedroom
11 Great room
12 Dining room



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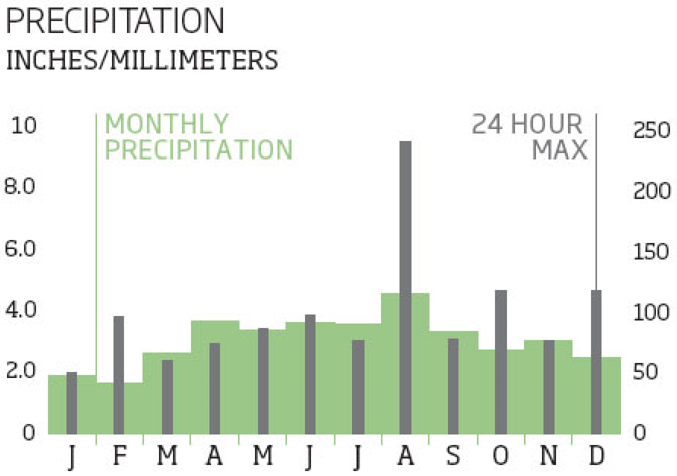


Heading degree days 6,479 F

Cooling degree days 782F

Solving the thermal bridge

The “classic” bad balcony detail results in heat loss as well as moisture and mold problems.

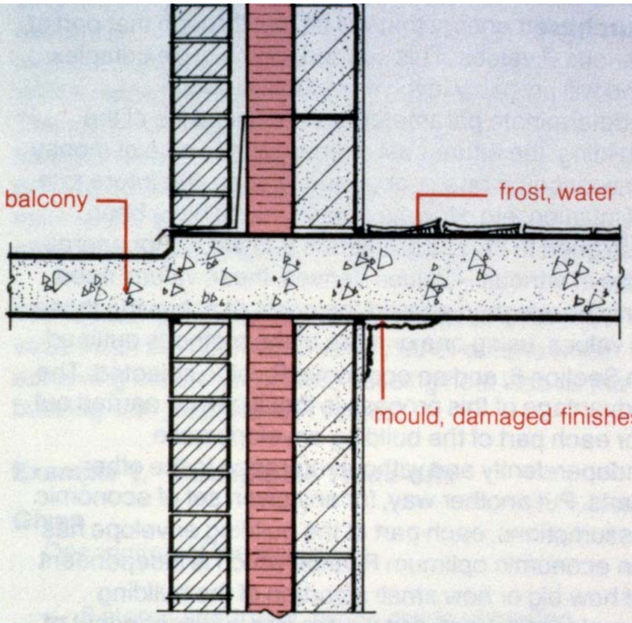


Figure 2.8A **Effect of Thermal Bridge When Indoor Relative Humidity is Appreciable (above 20% RH in midwinter)**

Meteorology - It all starts here…

In the built environment, meteorology is the start of all design …

- **Structural design / response**
- **Pedestrian comfort**
- **Air quality / plume dispersion**
- **Energy demand / heating and cooling loads**

etc.

Can’t we always use meteorological measurements?

Meteorology 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?

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

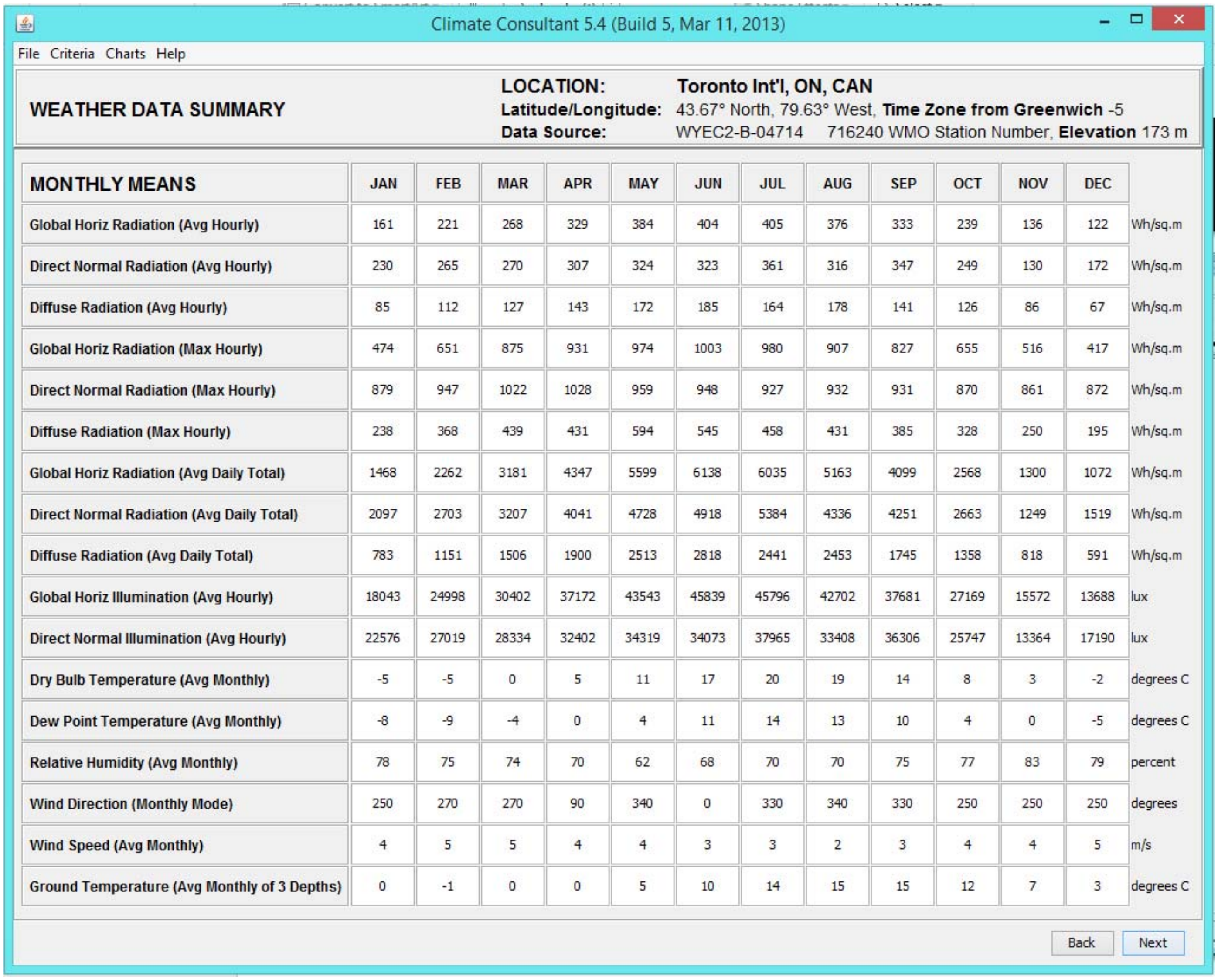
In naturally ventilated spaces where occupants can open and close windows, their thermal response will depend in part on the outdoor climate, and may have a wider comfort range than in buildings with centralized HVAC systems.

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

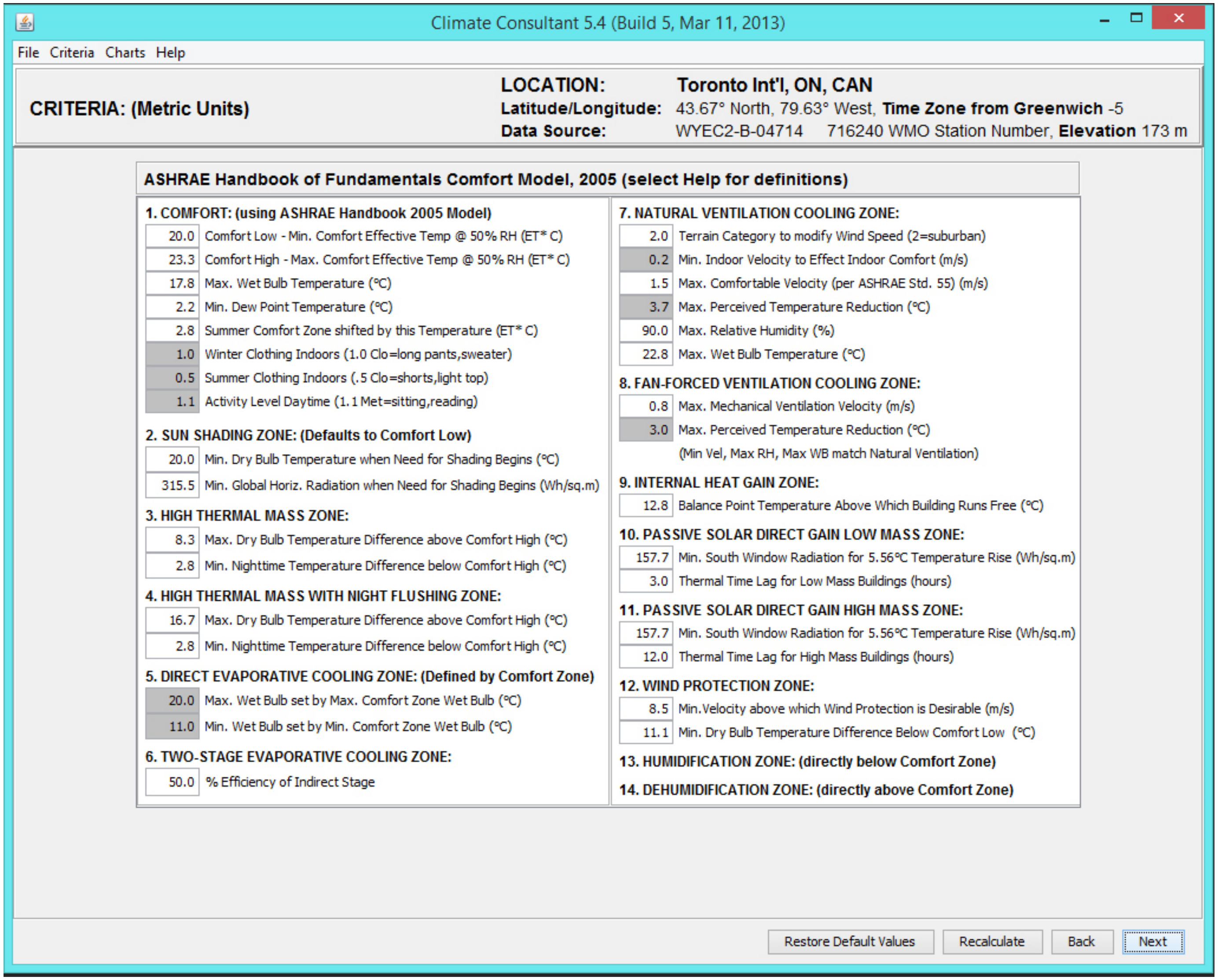


WEATHER DATA SUMMARY

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

Setting the Project Criteria



CRITERIA: (Metric Units)

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ASHRAE Handbook of Fundamentals Comfort Model, 2005 (select Help for definitions)

1. COMFORT: (using ASHRAE Handbook 2005 Model)

20.0	Comfort Low - Min. Comfort Effective Temp @ 50% RH (ET* C)
23.3	Comfort High - Max. Comfort Effective Temp @ 50% RH (ET* C)
17.8	Max. Wet Bulb Temperature (°C)
2.2	Min. Dew Point Temperature (°C)
2.8	Summer Comfort Zone shifted by this Temperature (ET* C)
1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)

2. SUN SHADING ZONE: (Defaults to Comfort Low)

20.0	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

8.3	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

16.7	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
11.0	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

50.0	% Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:

2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)
3.7	Max. Perceived Temperature Reduction (°C)
90.0	Max. Relative Humidity (%)
22.8	Max. Wet Bulb Temperature (°C)

8. FAN-FORCED VENTILATION COOLING ZONE:

0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C)

(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE:

12.8	Balance Point Temperature Above Which Building Runs Free (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)

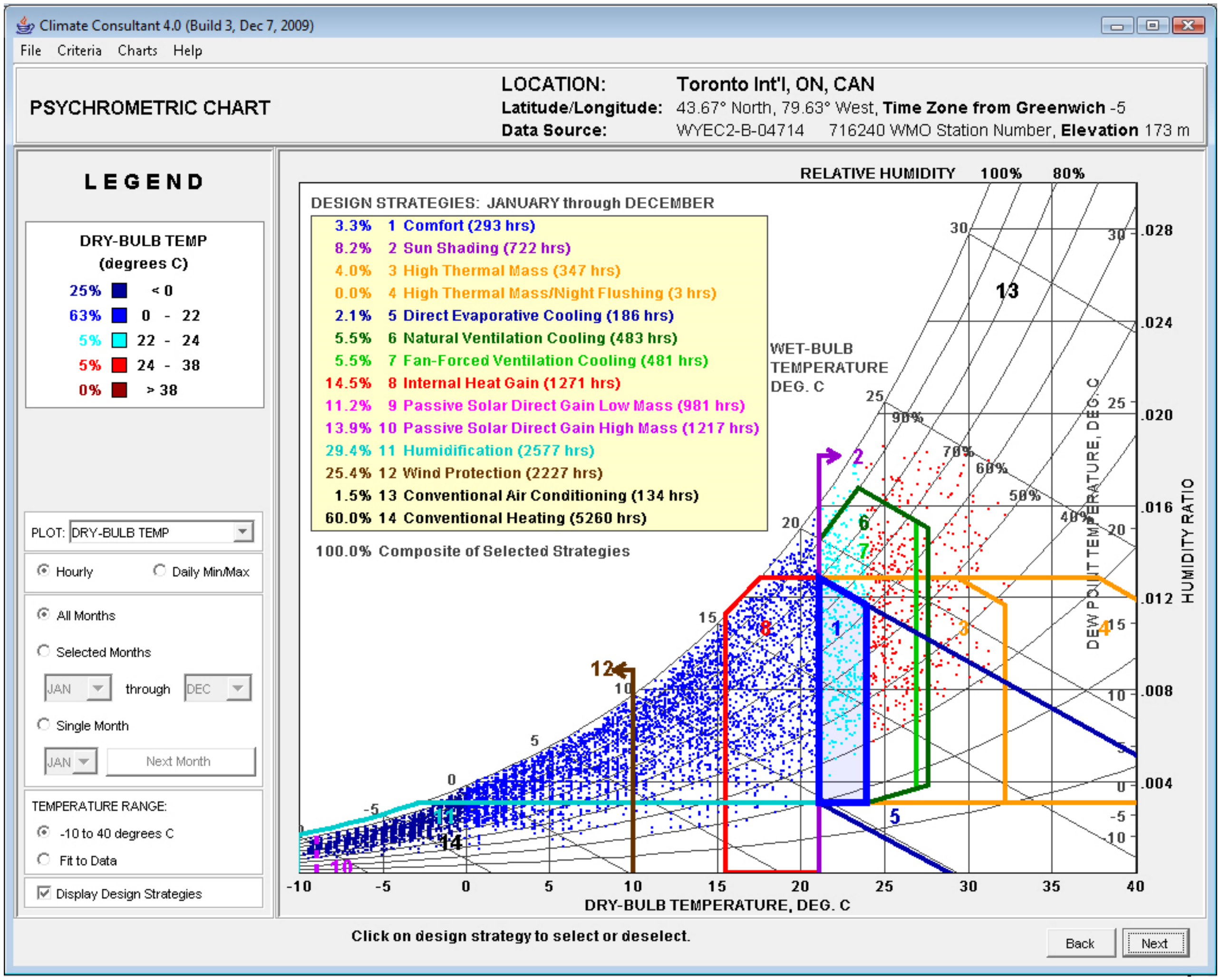
12. WIND PROTECTION ZONE:

8.5	Min.Velocity above which Wind Protection is Desirable (m/s)
11.1	Min. Dry Bulb Temperature Difference Below Comfort Low (°C)

13. HUMIDIFICATION ZONE: (directly below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (directly above Comfort Zone)

Psychrometric Chart



PSYCHROMETRIC CHART

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LEGEND

DRY-BULB TEMP
(degrees C)

25%	🟦	< 0
63%	🟦	0 - 22
5%	🟦	22 - 24
5%	🟥	24 - 38
0%	🟥	> 38

PLOT: DRY-BULB TEMP

● Hourly ○ Daily Min/Max

● All Months

○ Selected Months

JAN through DEC

○ Single Month

JAN Next Month

TEMPERATURE RANGE:

● -10 to 40 degrees C

○ Fit to Data

☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

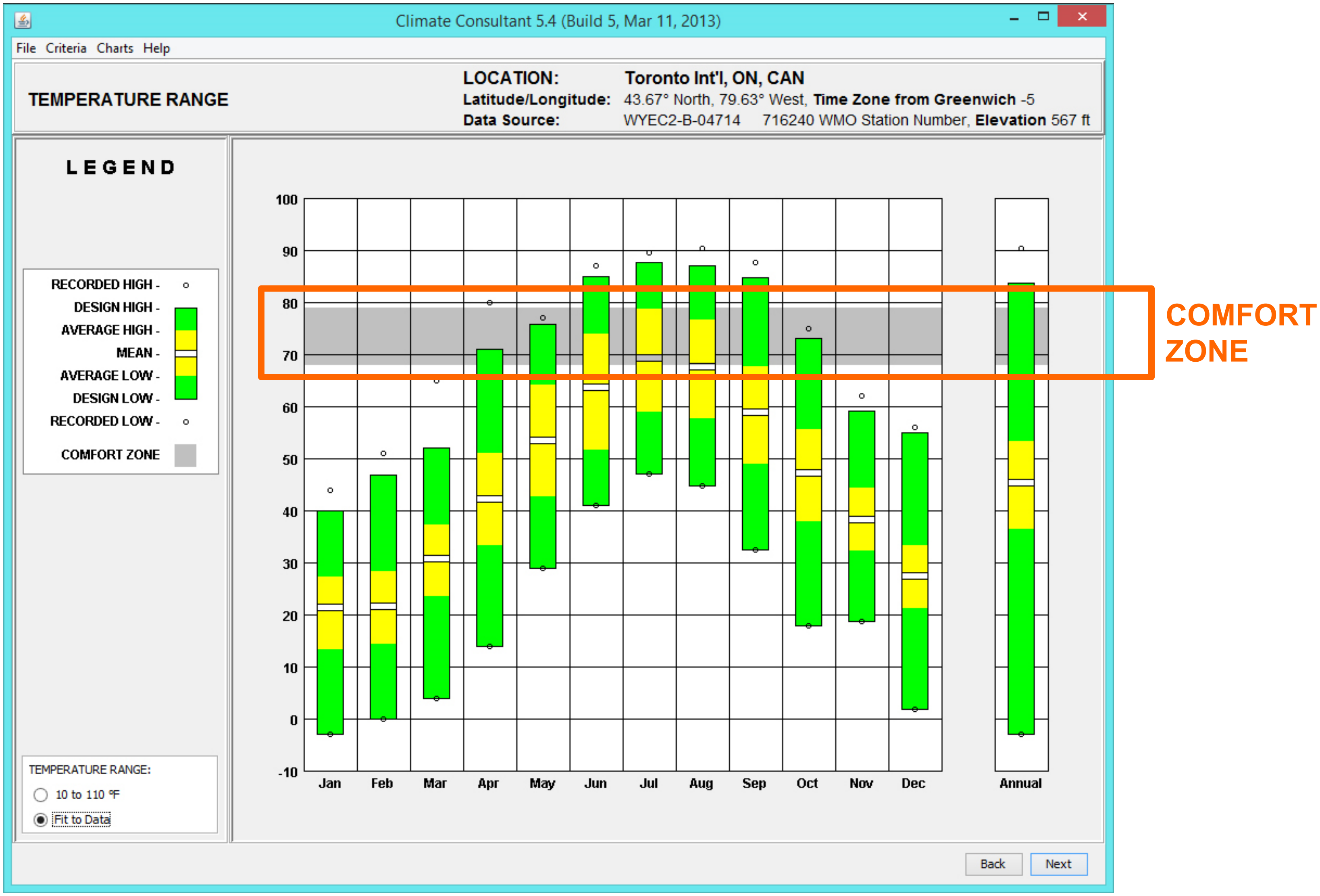
3.3%	1	Comfort (293 hrs)
8.2%	2	Sun Shading (722 hrs)
4.0%	3	High Thermal Mass (347 hrs)
0.0%	4	High Thermal Mass/Night Flushing (3 hrs)
2.1%	5	Direct Evaporative Cooling (186 hrs)
5.5%	6	Natural Ventilation Cooling (483 hrs)
5.5%	7	Fan-Forced Ventilation Cooling (481 hrs)
14.5%	8	Internal Heat Gain (1271 hrs)
11.2%	9	Passive Solar Direct Gain Low Mass (981 hrs)
13.9%	10	Passive Solar Direct Gain High Mass (1217 hrs)
29.4%	11	Humidification (2577 hrs)
25.4%	12	Wind Protection (2227 hrs)
1.5%	13	Conventional Air Conditioning (134 hrs)
60.0%	14	Conventional Heating (5260 hrs)

100.0% Composite of Selected Strategies

Click on design strategy to select or deselect.

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

Climate Data for Toronto



TEMPERATURE RANGE

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Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 567 ft

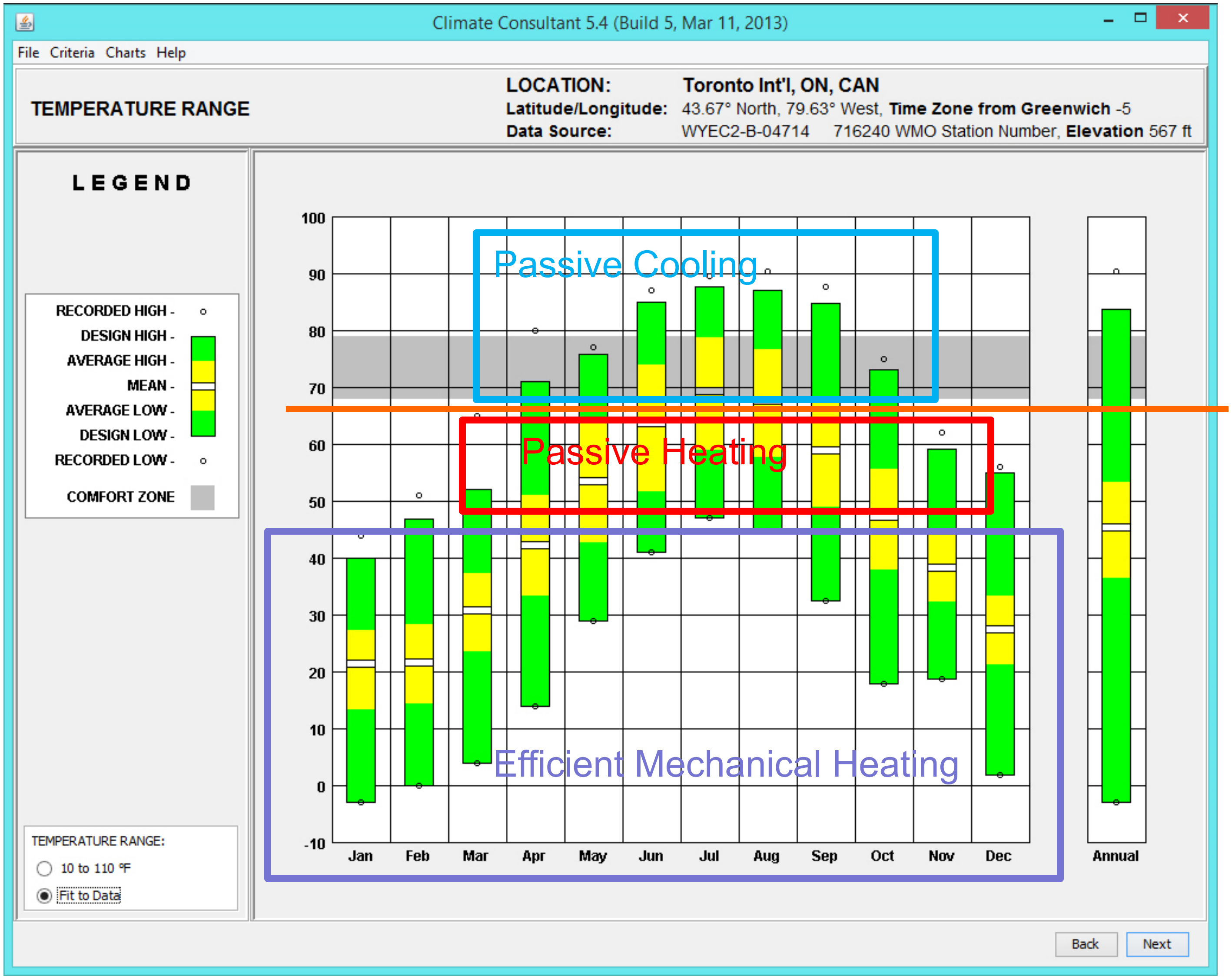
LEGEND

RECORDED HIGH - ○
DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW - ○
COMFORT ZONE ▨

TEMPERATURE RANGE:
○ 10 to 110 °F
● Fit to Data

COMFORT ZONE

Climate Data for Toronto



TEMPERATURE RANGE

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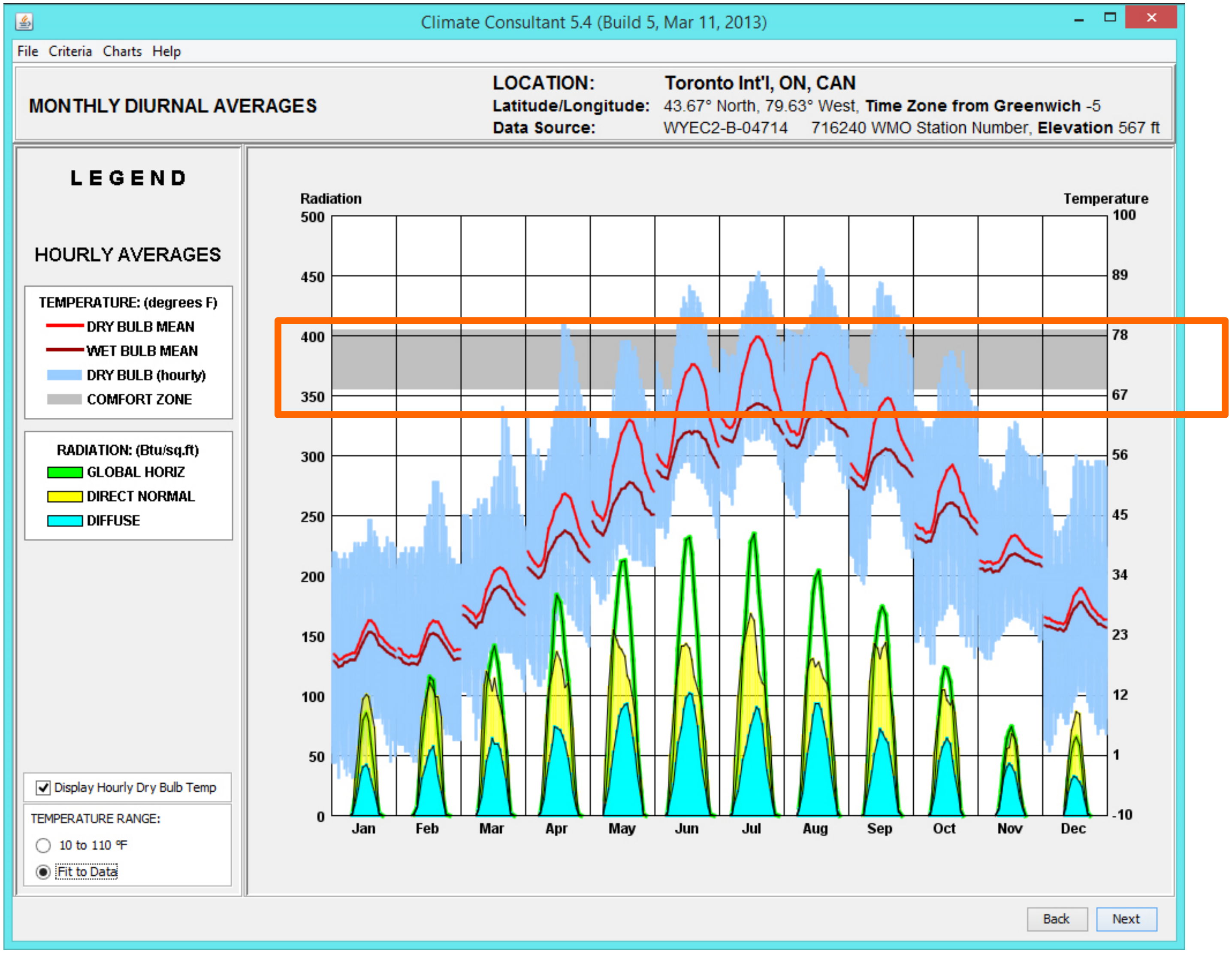
TEMPERATURE RANGE:
○ 10 to 110 °F
● Fit to Data

18^{o}C is the base point for measuring Heating vs Cooling Degree days

Climate Data for Toronto



MONTHLY DIURNAL AVERAGES

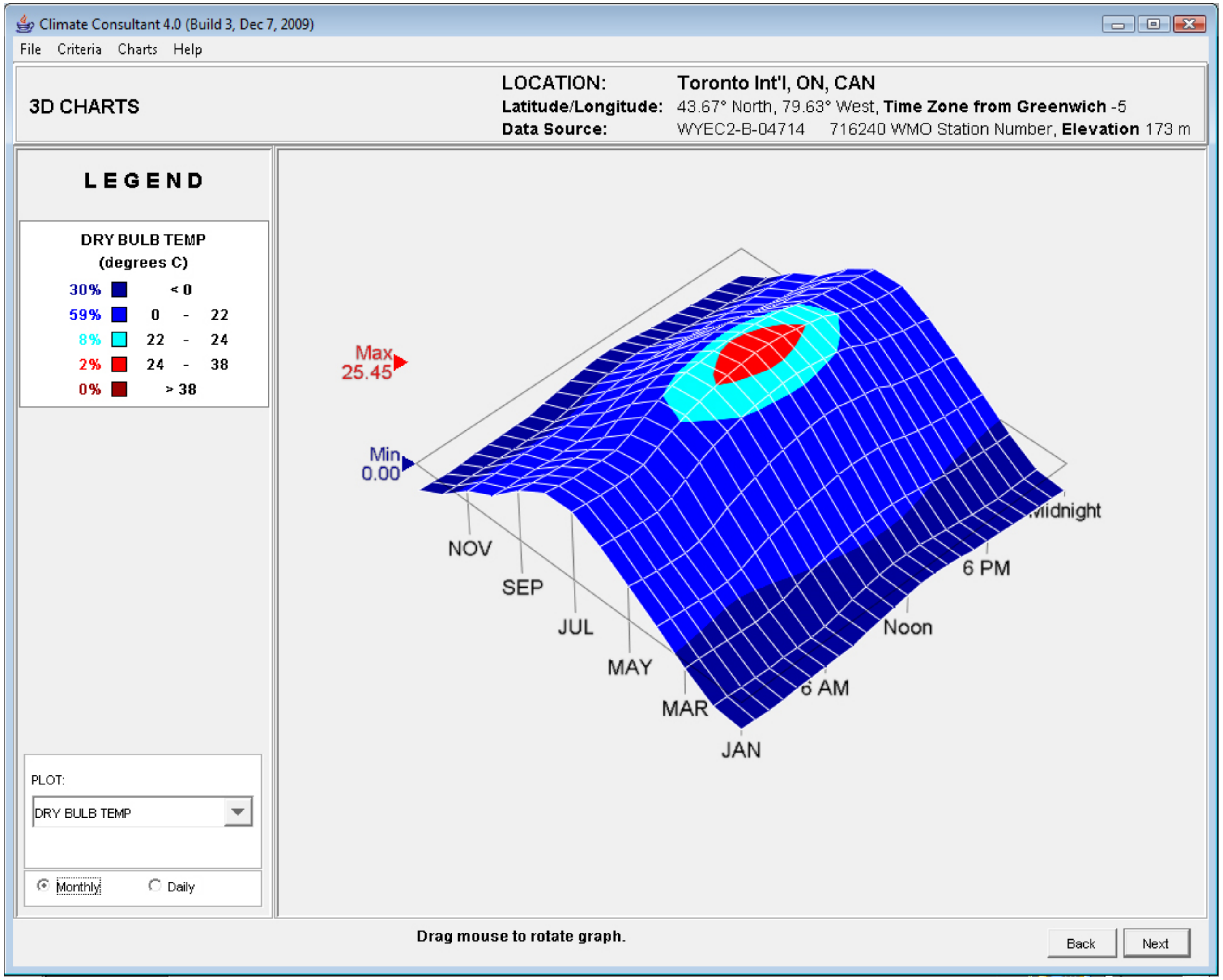
LOCATION: **Toronto Int'l, ON, CAN**
Latitude/Longitude: 43.67° North, 79.63° West, **Time Zone from Greenwich** -5
Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 567 ft

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
○ 10 to 110 °F
● Fit to Data

COMFORT ZONE

Temperature Range for Toronto



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DRY BULB TEMP
(degrees C)

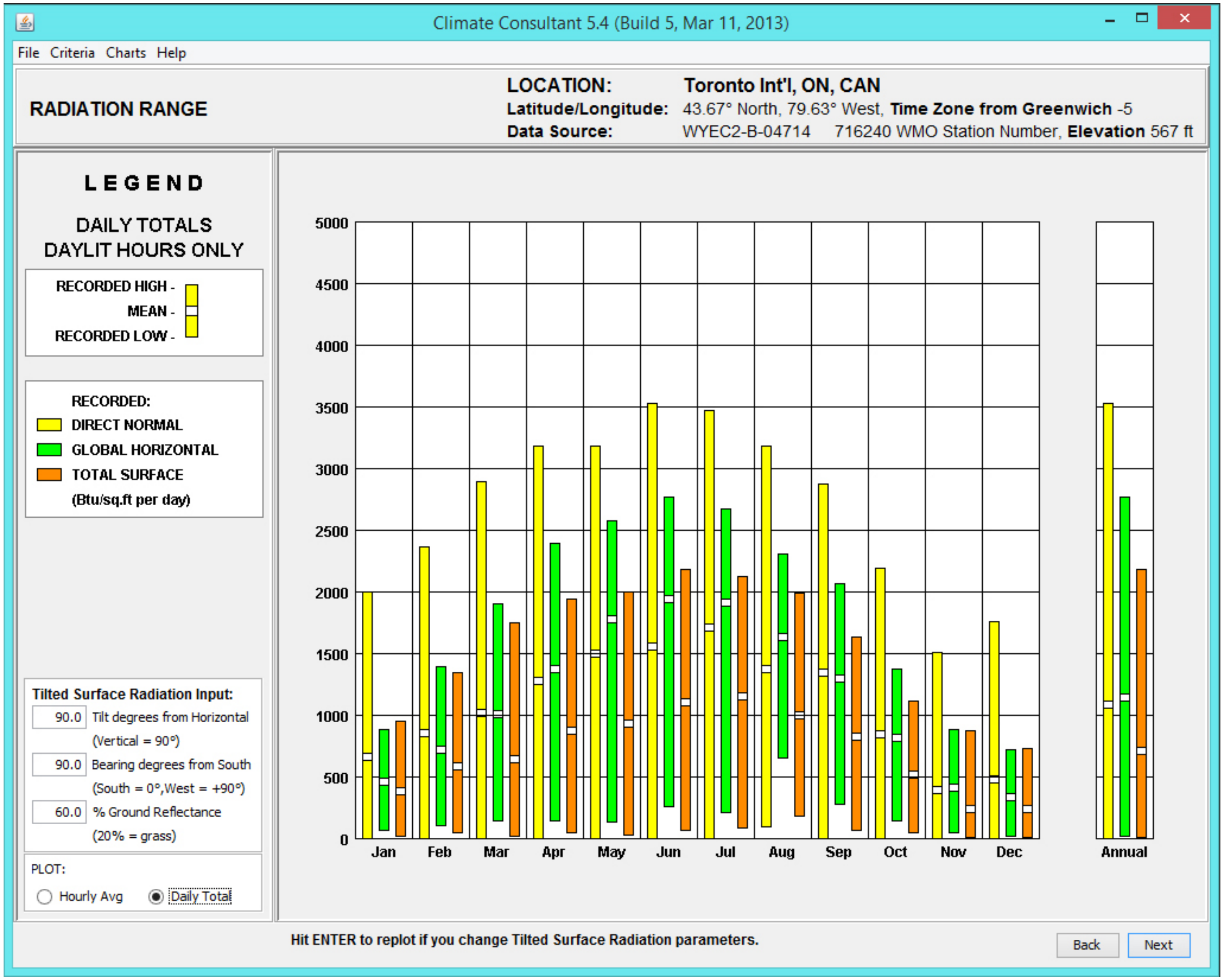
30%	🟦	< 0
59%	🟦	0 - 22
8%	🟦	22 - 24
2%	🟥	24 - 38
0%	🟥	> 38

PLOT: DRY BULB TEMP

● Monthly ○ Daily

Drag mouse to rotate graph.

Toronto Solar Radiation Range



RADIATION RANGE

LOCATION: **Toronto Int'l, ON, CAN**
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Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 567 ft

LEGEND

DAILY TOTALS
DAYLIT HOURS ONLY

RECORDED HIGH -
MEAN -
RECORDED LOW -

RECORDED:
🟨 DIRECT NORMAL
🟩 GLOBAL HORIZONTAL
🟧 TOTAL SURFACE
(Btu/sq.ft per day)

Tilted Surface Radiation Input:

90.0 Tilt degrees from Horizontal
(Vertical = 90°)

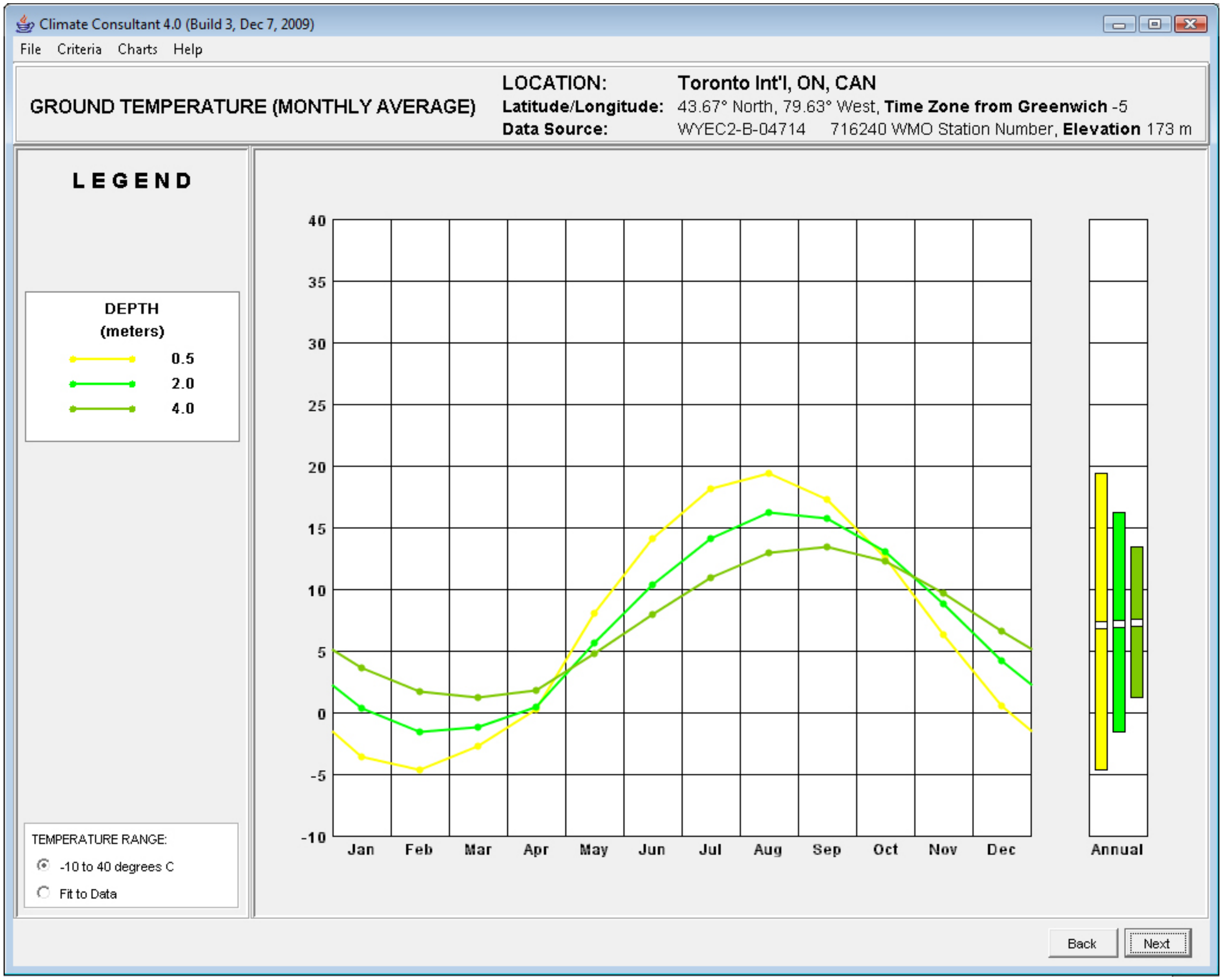
90.0 Bearing degrees from South
(South = 0°,West = +90°)

60.0 % Ground Reflectance
(20% = grass)

PLOT:
○ Hourly Avg ● Daily Total

Hit ENTER to replot if you change Tilted Surface Radiation parameters.

Ground Temperature for Toronto

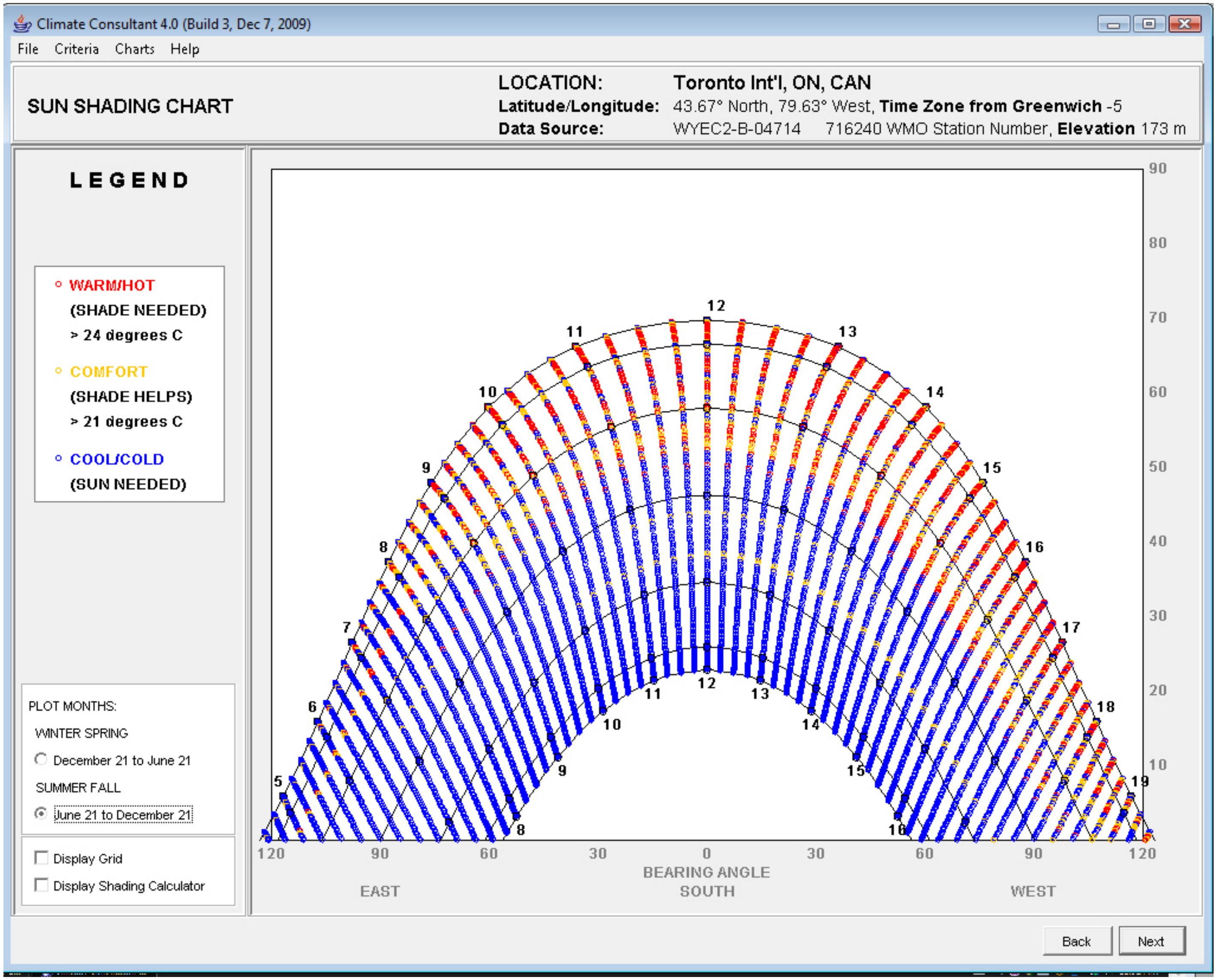


GROUND TEMPERATURE (MONTHLY AVERAGE)

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

TEMPERATURE RANGE:
● -10 to 40 degrees C
○ Fit to Data

Sun Shading Chart



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

SUN SHADING CHART

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

- ● WARM/HOT (SHADE NEEDED) > 24 degrees C
- ● COMFORT (SHADE HELPS) > 21 degrees C
- ● COOL/COLD (SUN NEEDED)

PLOT MONTHS:

WINTER SPRING

○ December 21 to June 21

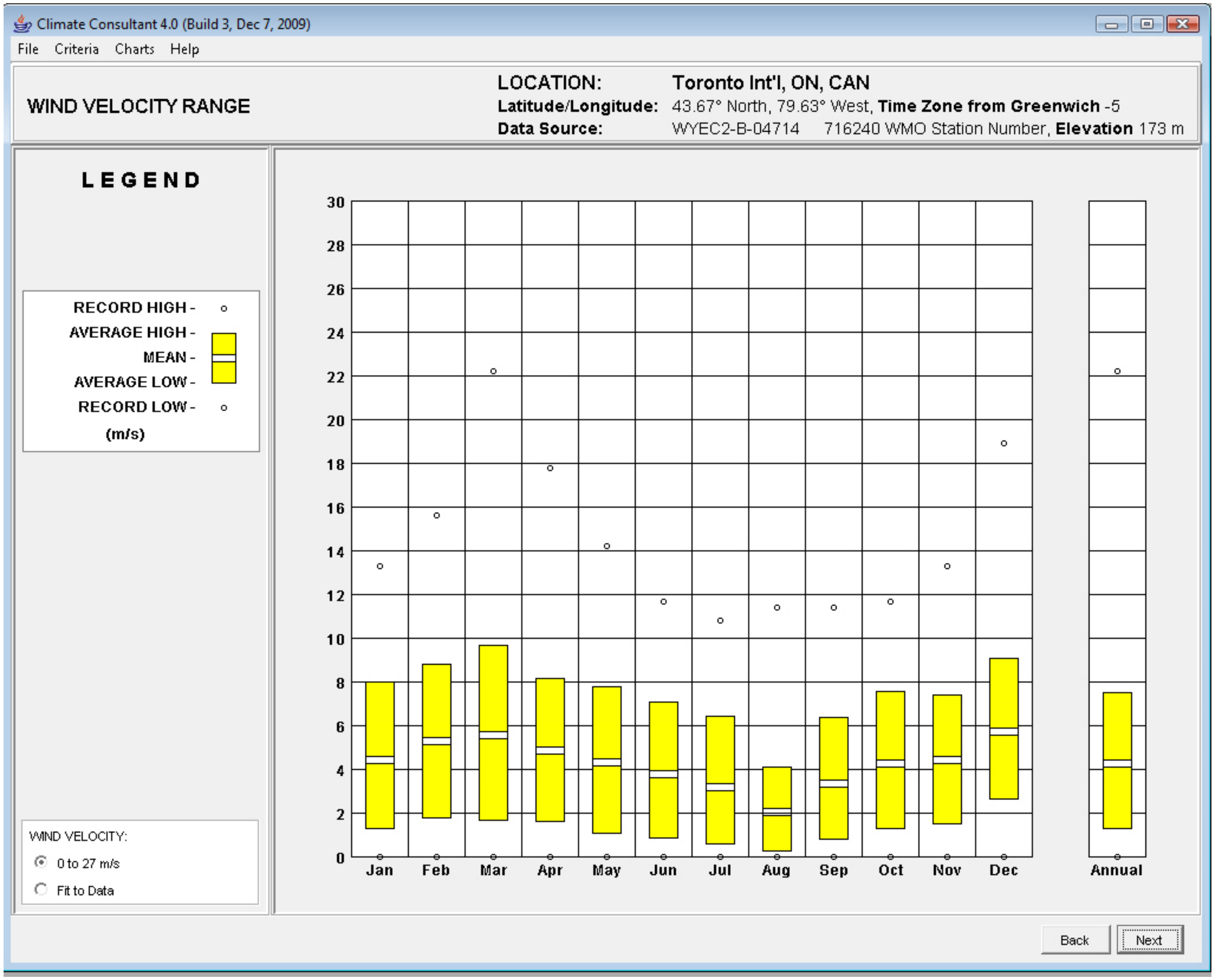
SUMMER FALL

● June 21 to December 21

☐ Display Grid

☐ Display Shading Calculator

Wind Speed



WIND VELOCITY RANGE

LOCATION: Toronto Int'l, ON, CAN

Latitude/Longitude: 43.67° North, 79.63° West, **Time Zone from Greenwich** -5

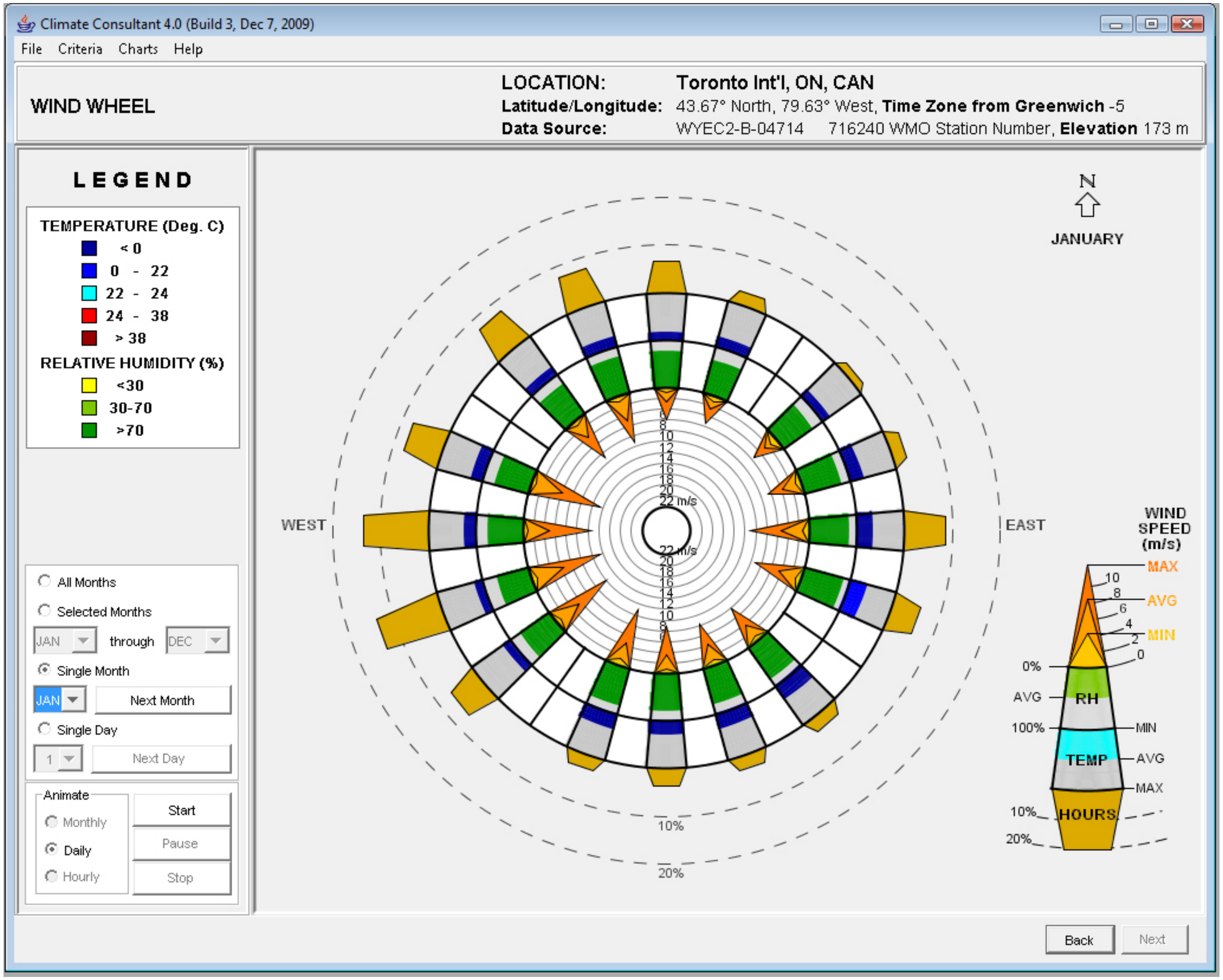
Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 173 m

WIND VELOCITY:

● 0 to 27 m/s

○ Fit to Data

January Wind Wheel/Rose for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

WIND WHEEL

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

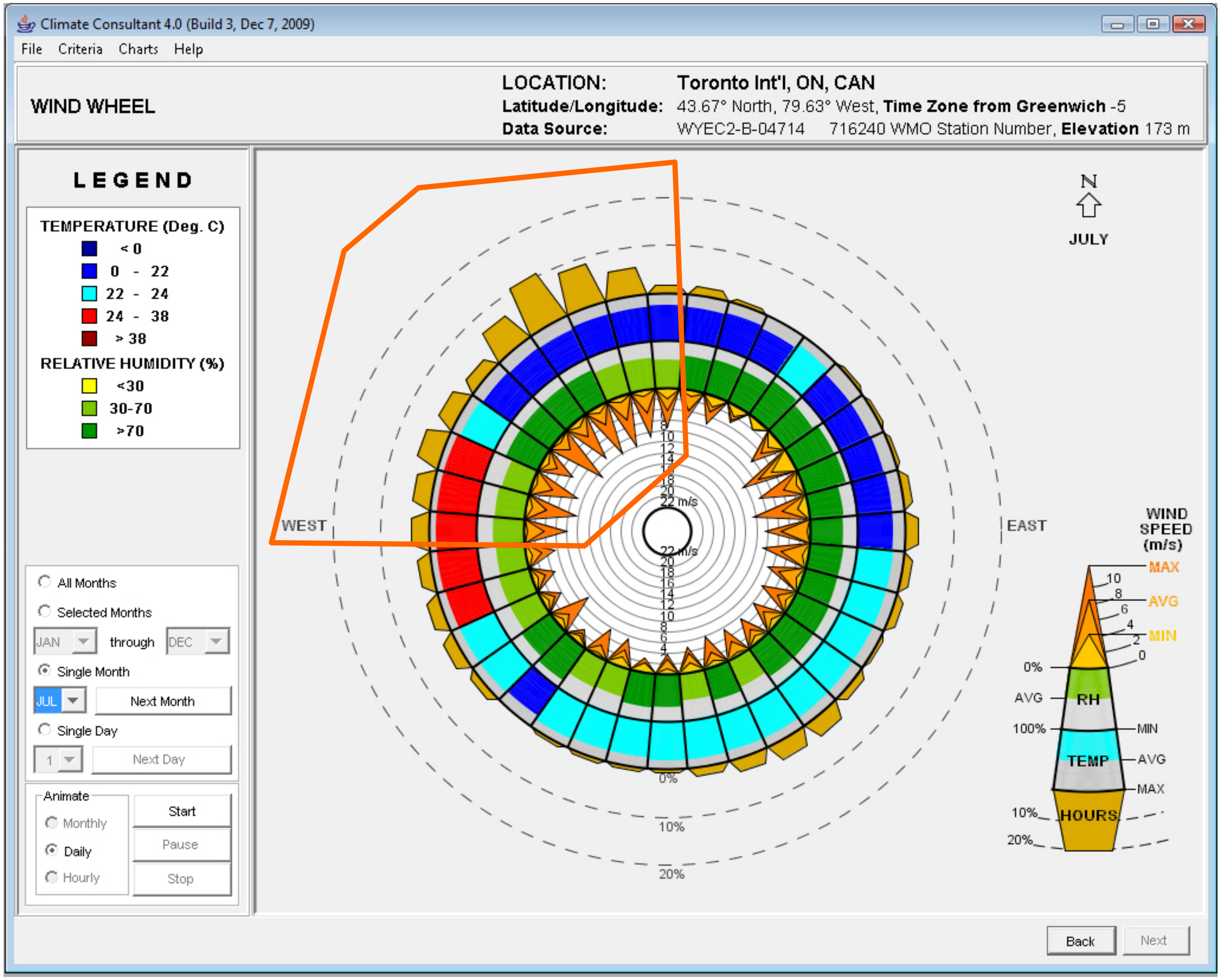
TEMPERATURE (Deg. C)
- 🟦 < 0
- 🟦 0 - 22
- 🟦 22 - 24
- 🟥 24 - 38
- 🟥 > 38

RELATIVE HUMIDITY (%)
- 🟨 <30
- 🟩 30-70
- 🟩 >70

○ All Months
○ Selected Months
JAN through DEC
● Single Month
JAN
○ Single Day
1

Animate
○ Monthly
● Daily
○ Hourly

July Wind Wheel/Rose for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

WIND WHEEL

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

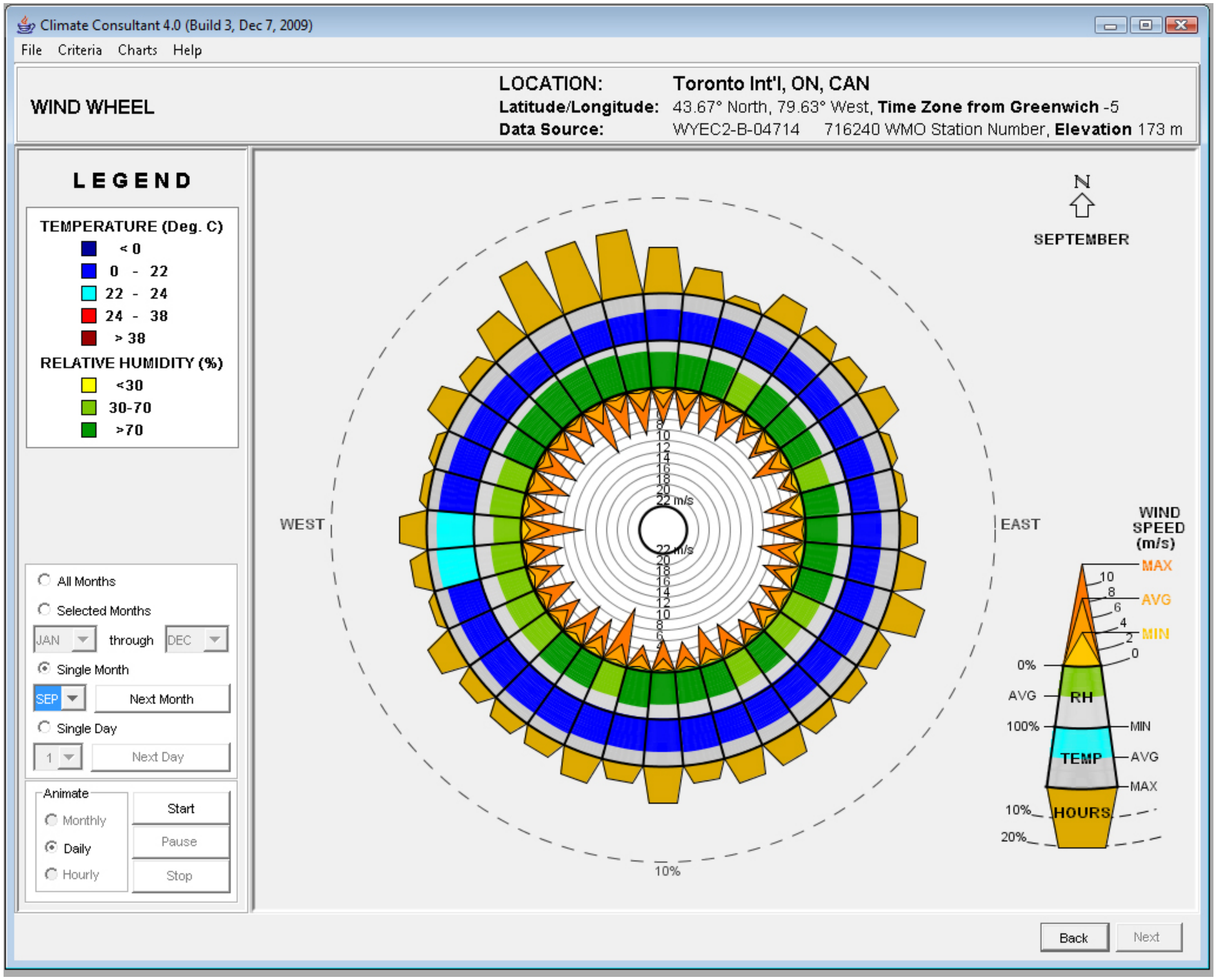
TEMPERATURE (Deg. C)
- 🟦 < 0
- 🟦 0 - 22
- 🟦 22 - 24
- 🟥 24 - 38
- 🟥 > 38

RELATIVE HUMIDITY (%)
- 🟨 <30
- 🟩 30-70
- 🟩 >70

○ All Months
○ Selected Months
JAN through DEC
● Single Month
JUL
○ Single Day
1

Animate
○ Monthly
● Daily
○ Hourly

September Wind Wheel/Rose for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

WIND WHEEL

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

TEMPERATURE (Deg. C)
- 🟦 < 0
- 🟦 0 - 22
- 🟦 22 - 24
- 🟥 24 - 38
- 🟥 > 38

RELATIVE HUMIDITY (%)
- 🟨 <30
- 🟩 30-70
- 🟩 >70

- ○ All Months
- ○ Selected Months
- JAN through DEC
- ● Single Month
- SEP
- ○ Single Day
- 1

Animate
- ○ Monthly
- ● Daily
- ○ Hourly

Source of EPW Data

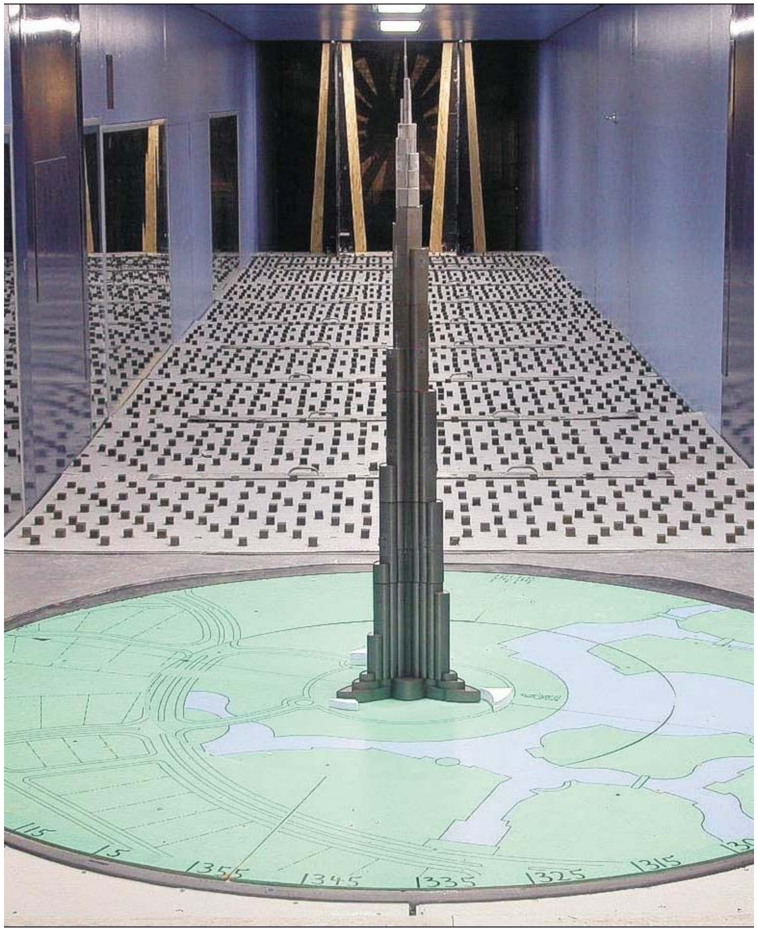
Story of TMY data gathering:

- 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

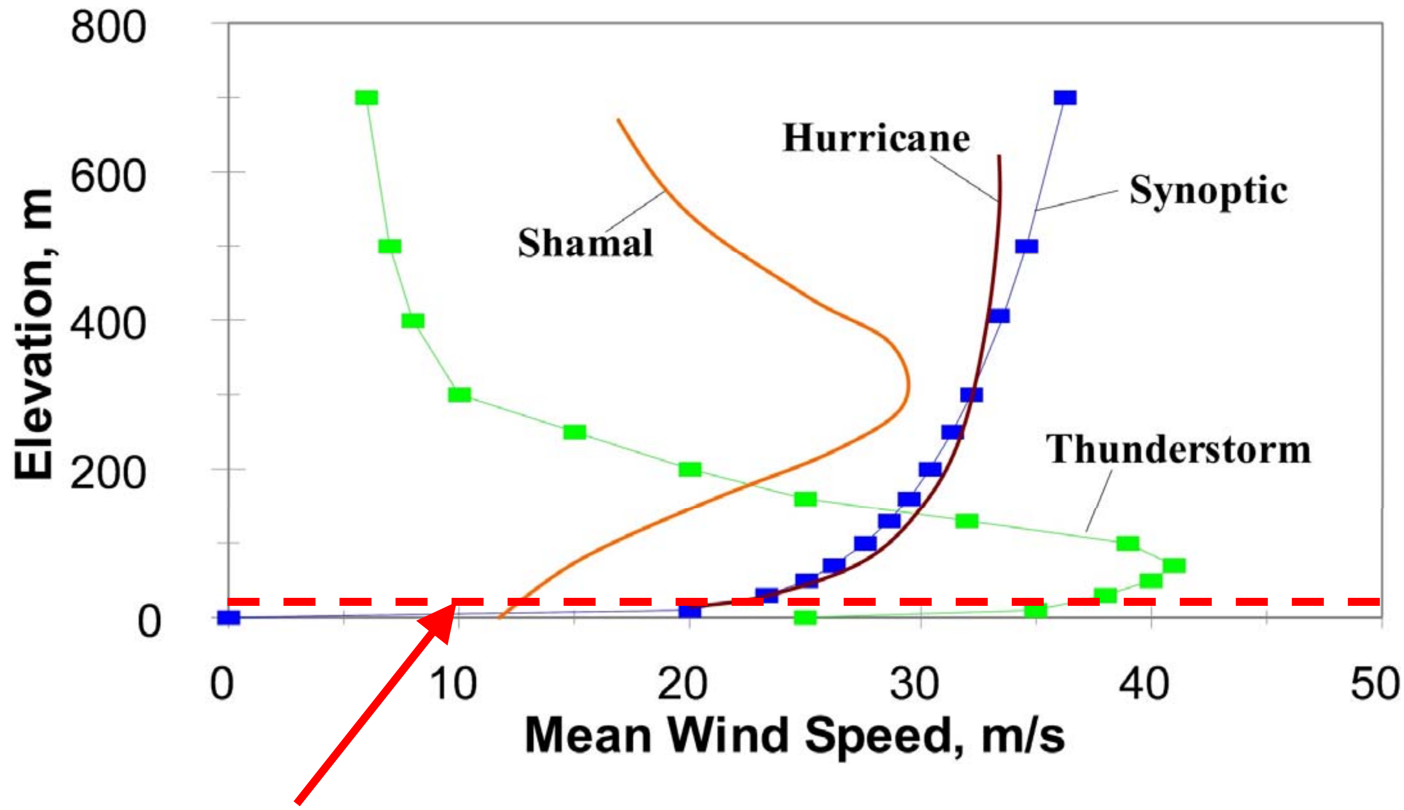
Sometimes the Met Data is Lacking

Burj Khalifa – 820 m tall

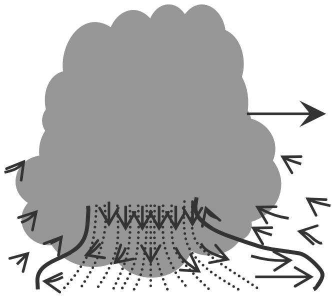
Wind measured at ground level is not good enough



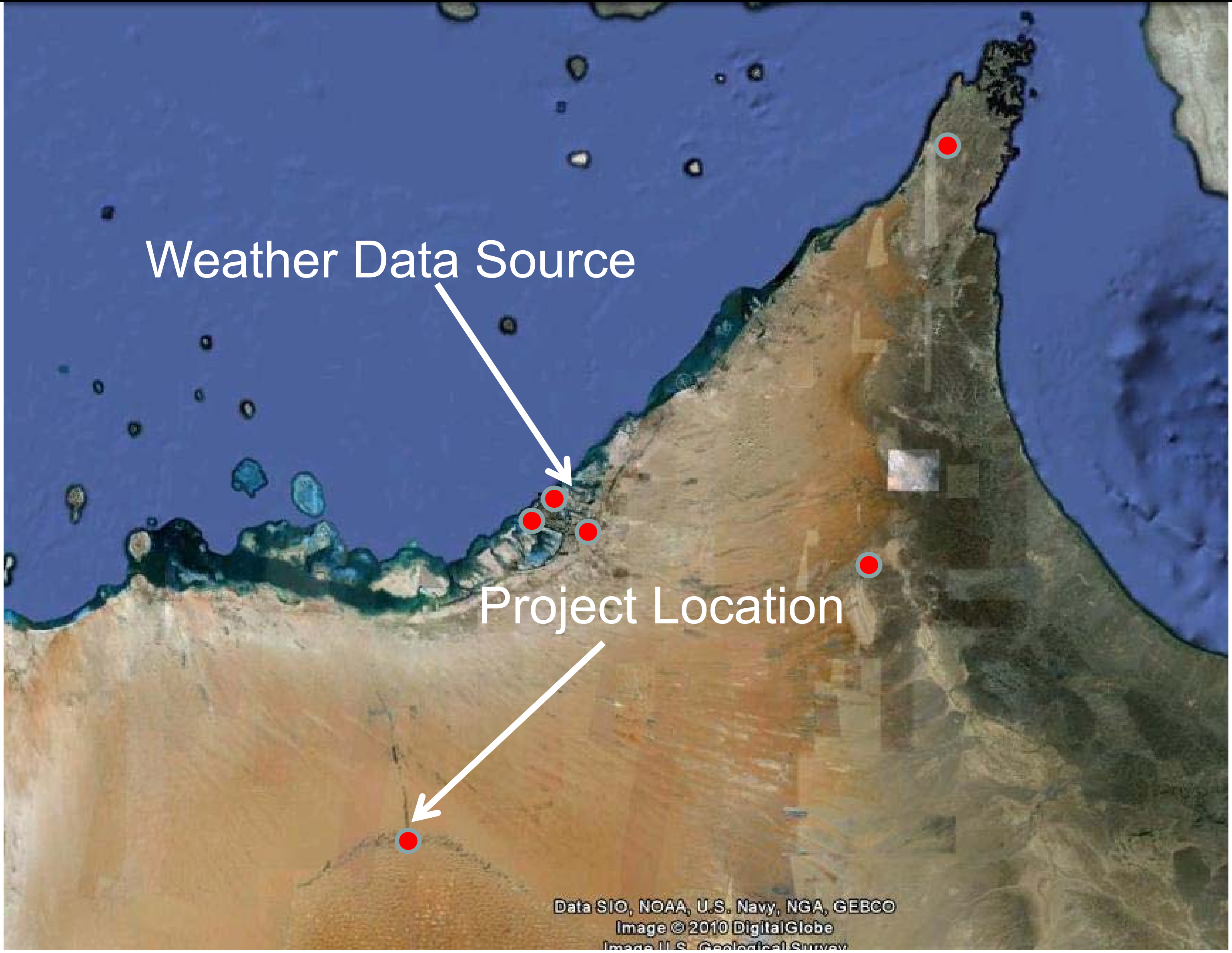
Wind Profile



Historical wind data recorded at surface level

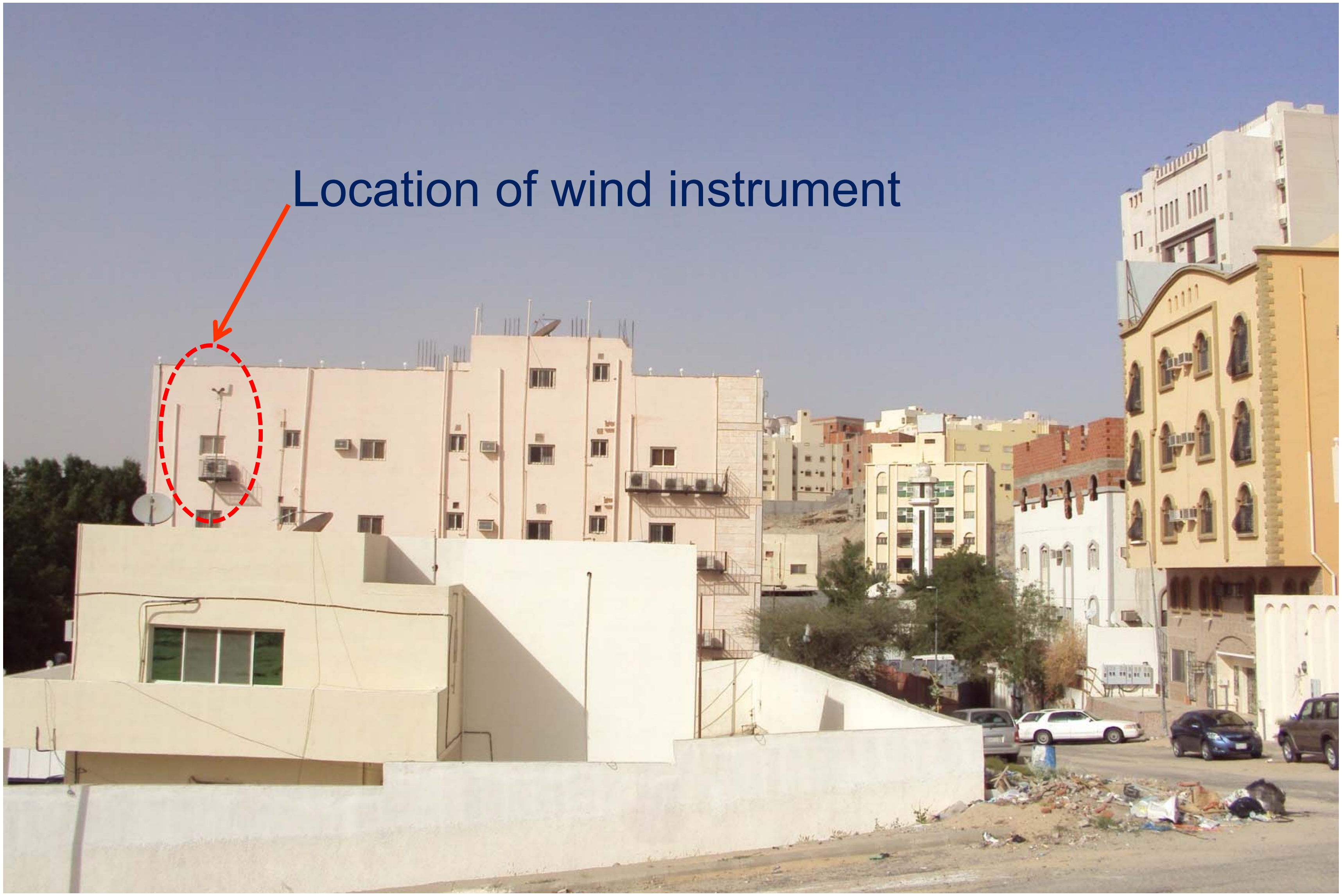


Sometimes the Met Data Is Not Valid



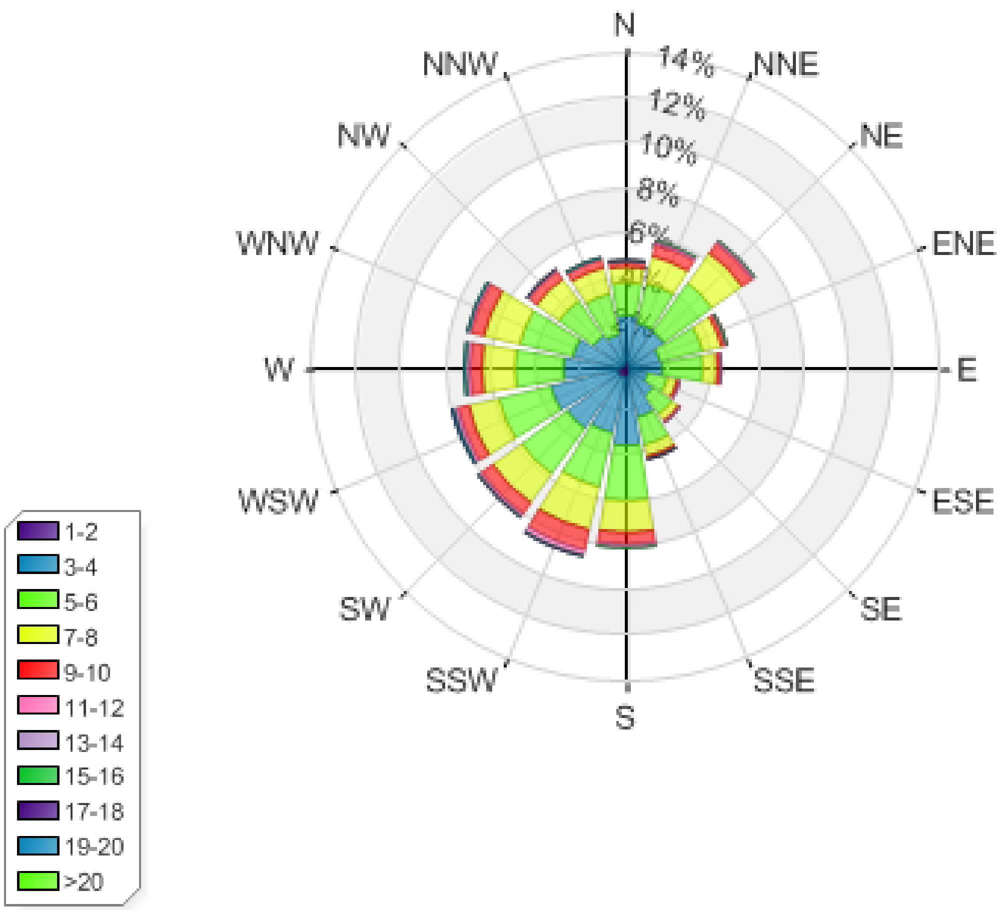
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 DigitalGlobe
Image U.S. Geological Survey

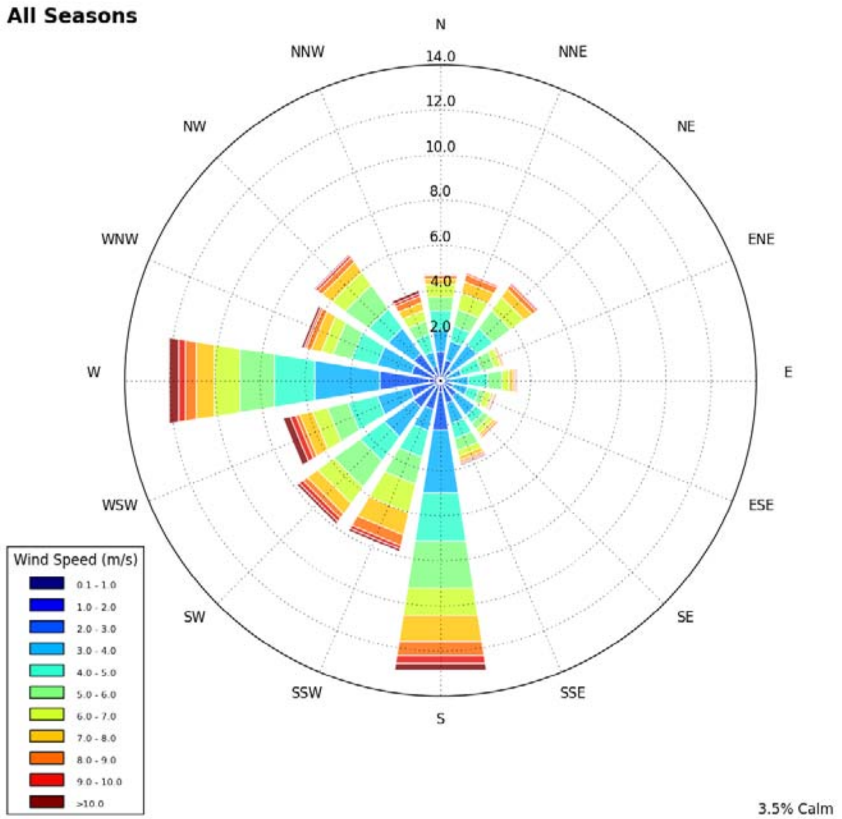
Sometimes the Met Data is Just Wrong



Sometimes the Data Filtering Affects Parameters

Directional Distribution (%) of Winds in m/s (Blowing From)
Chicago O'Hare International Airport, (1989-2009)





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.

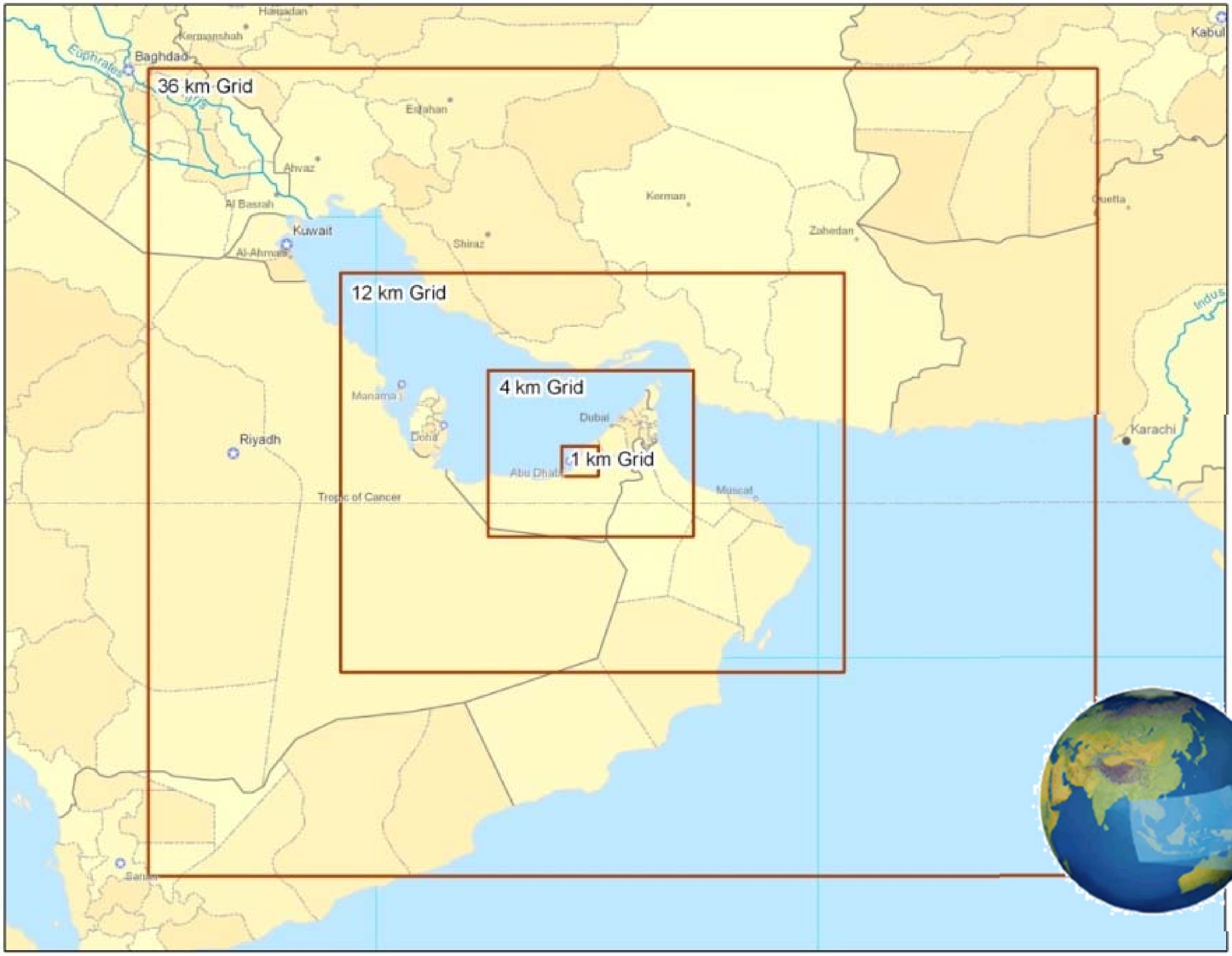
Diagnostic

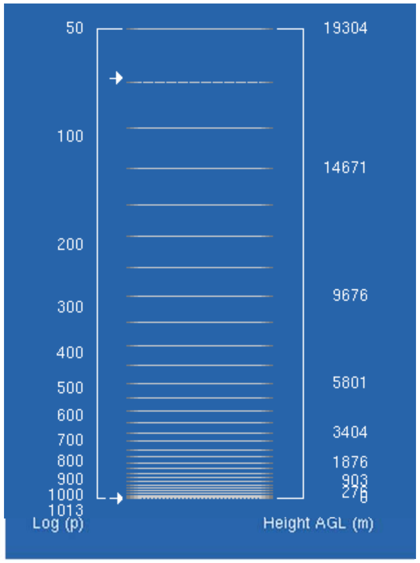
Dependent upon measurement data and involves 2-D or 3-D interpolation with limited physics where each hour is treated independently.

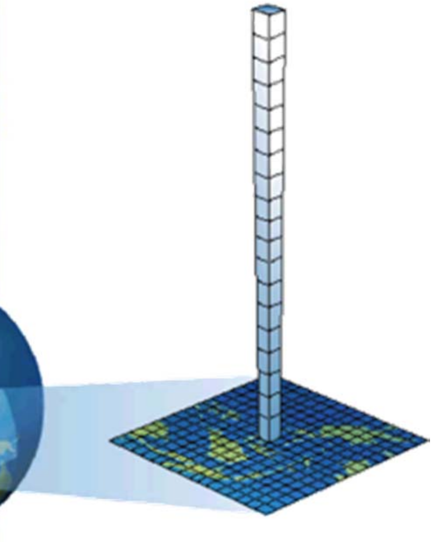
Prognostic

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

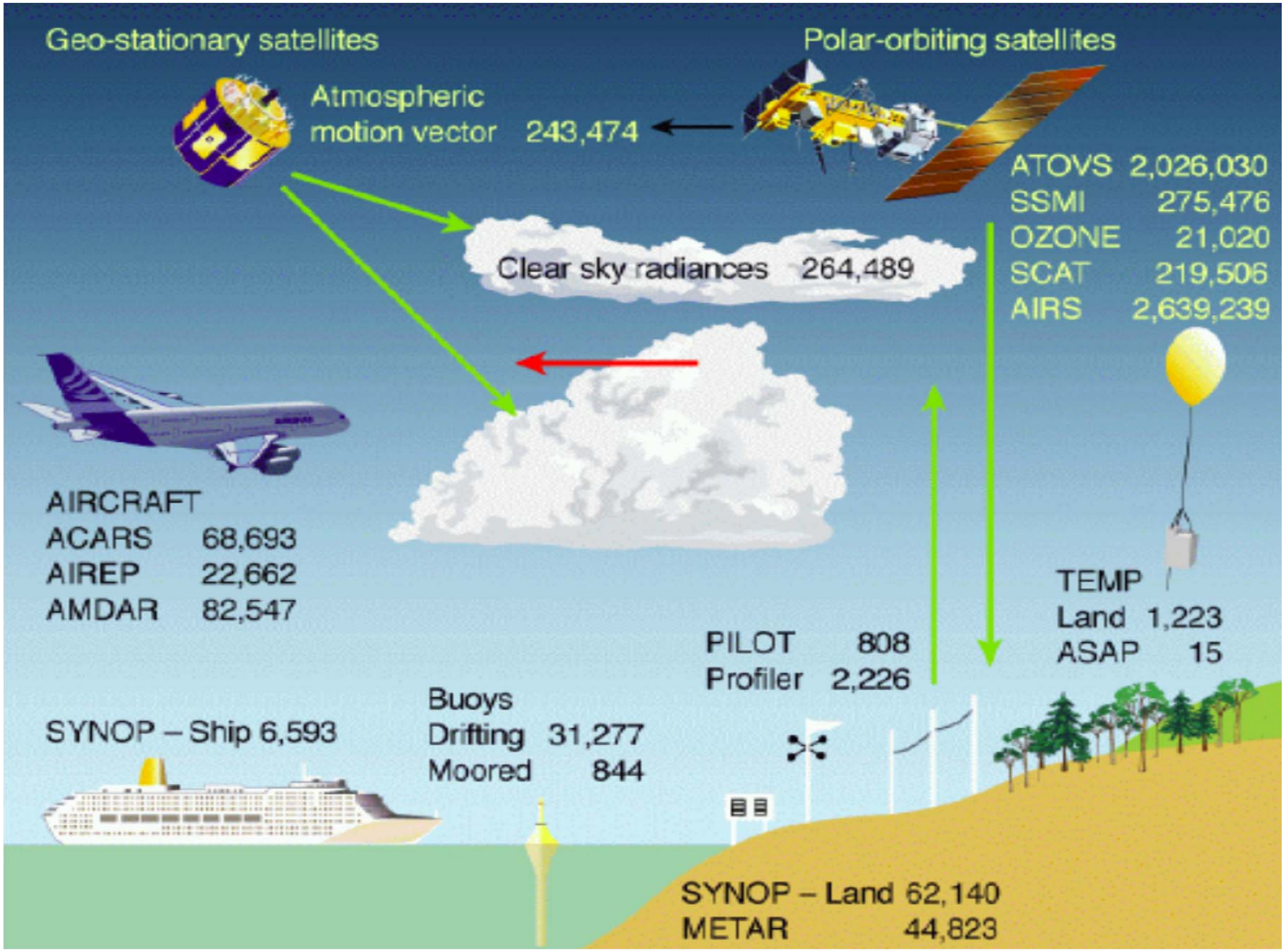
Prognostic modeling – nested grid paradigm





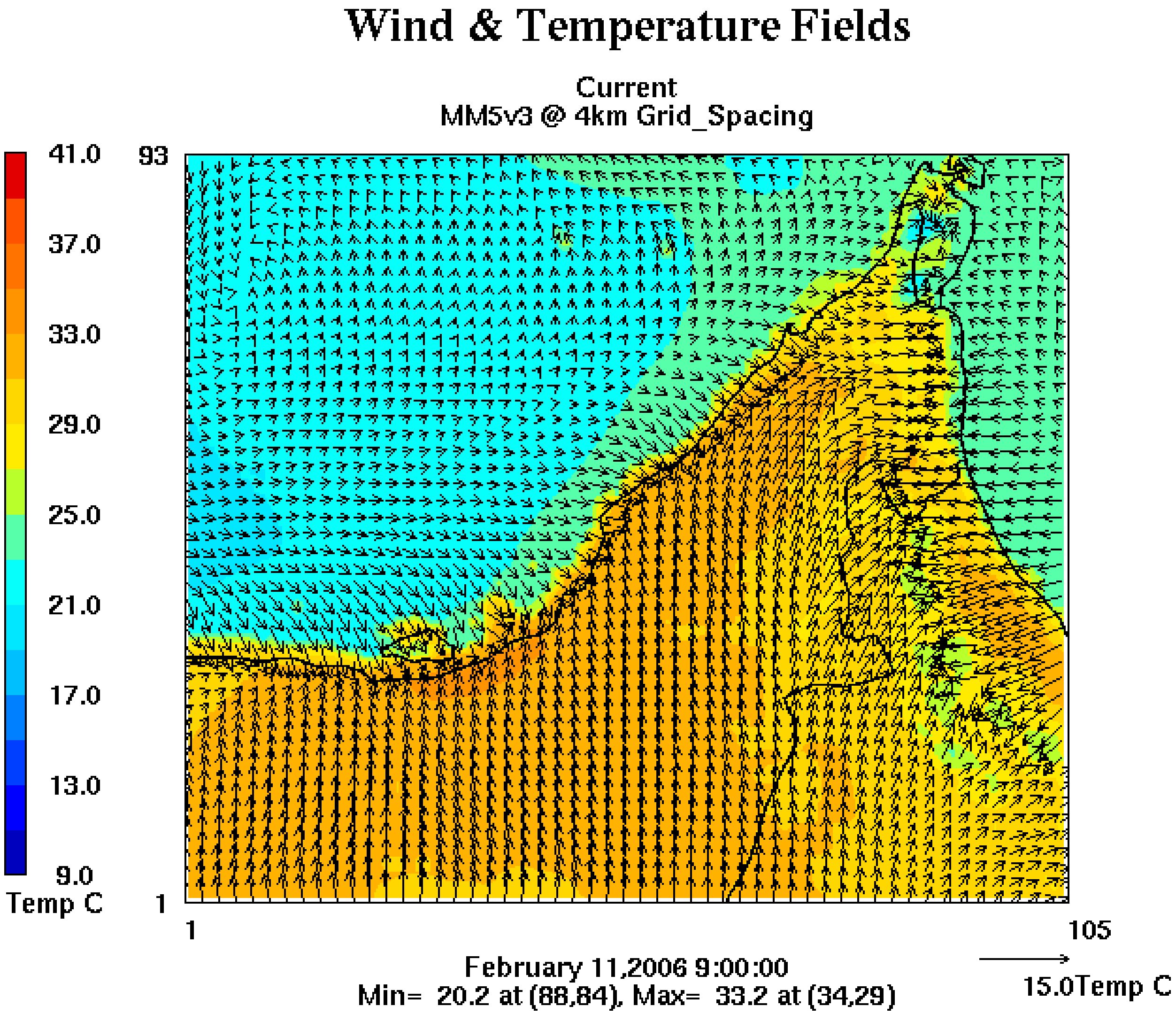


Prognostic modeling – nested grid paradigm



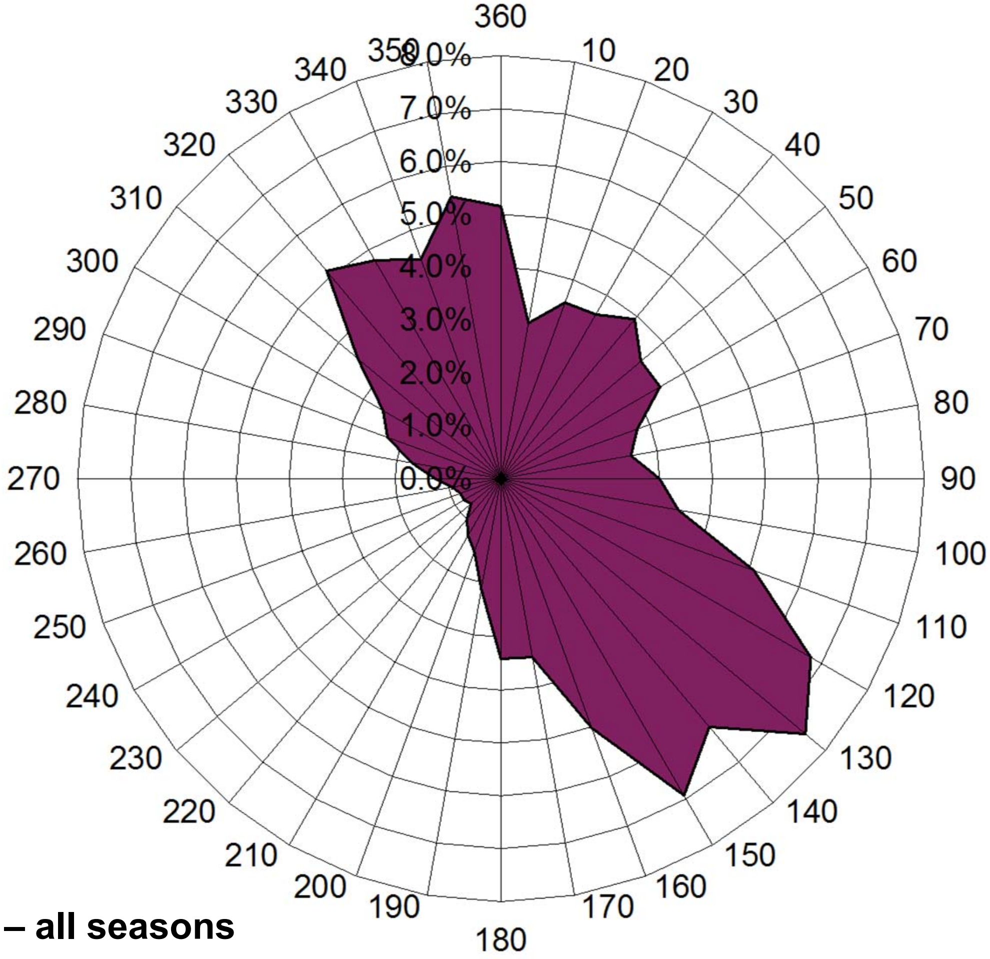
Study of UAE

- 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.



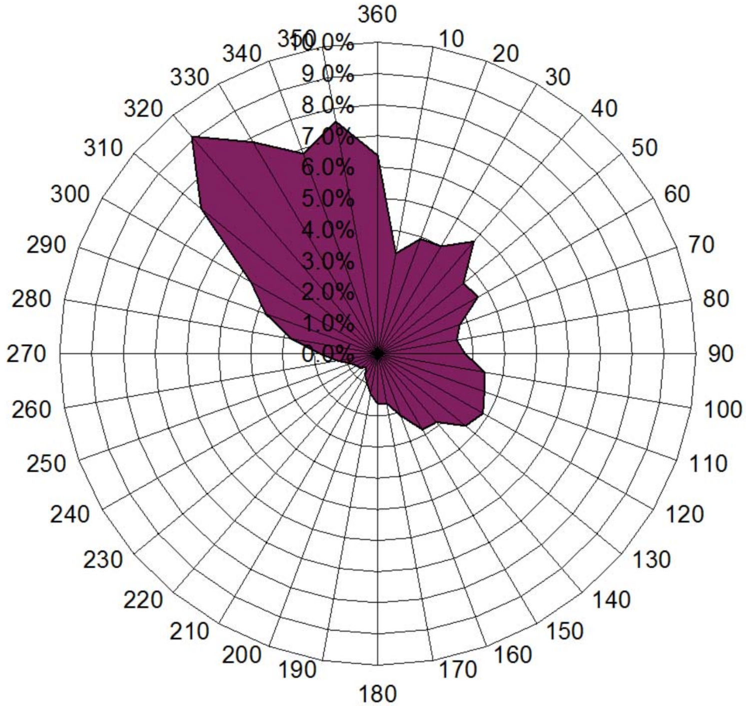
East China Sea - Shanghai

- The windrose shows where winds come from
- Wind is complex. It changes by:
  - **Season**
  - **Time of day**
  - **Specific location**

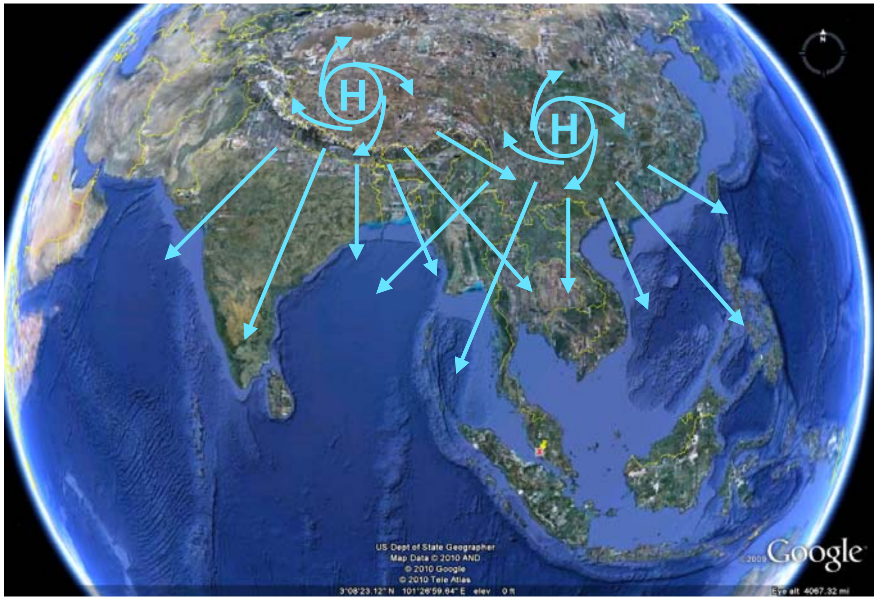


Winds in Shanghai – all seasons

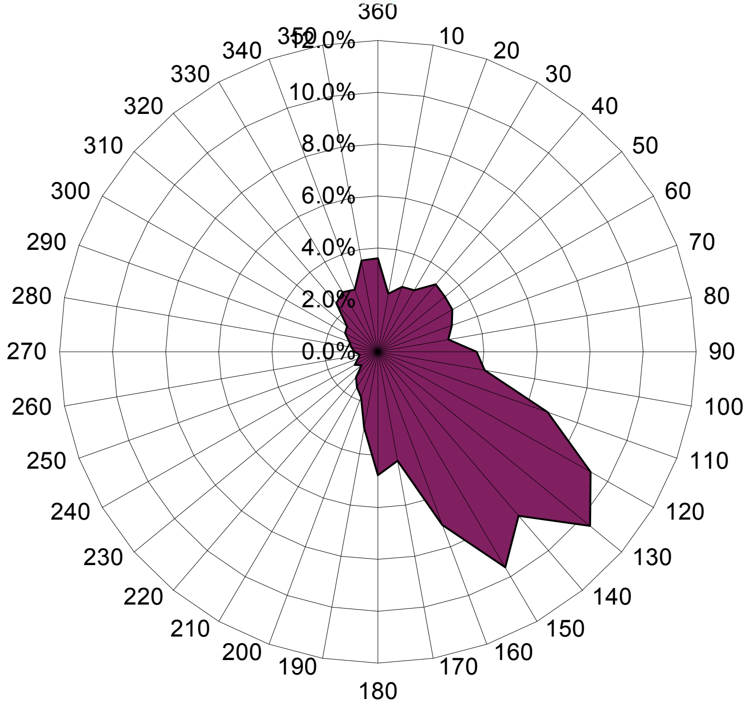
Winds in Shanghai –Winter



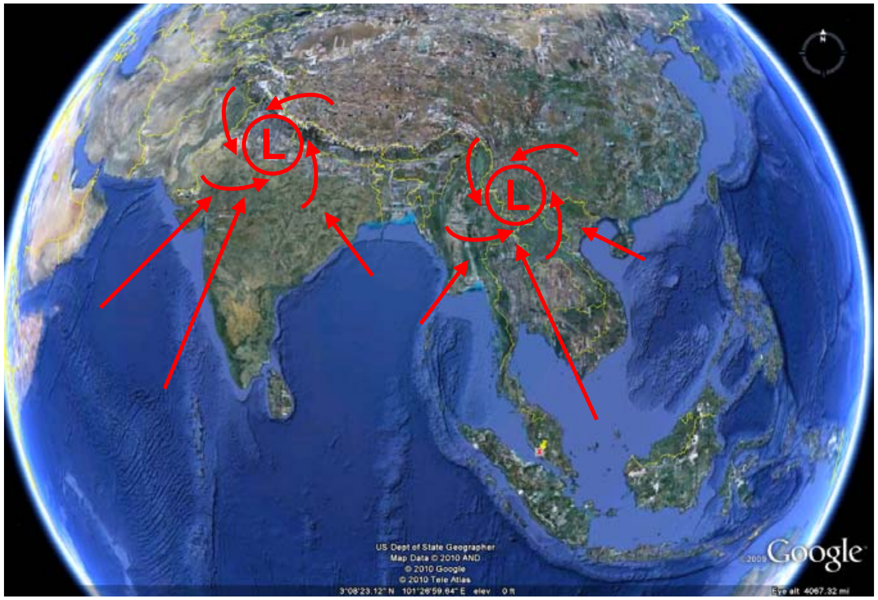
Northeast Monsoon
Northern Hemisphere Winter



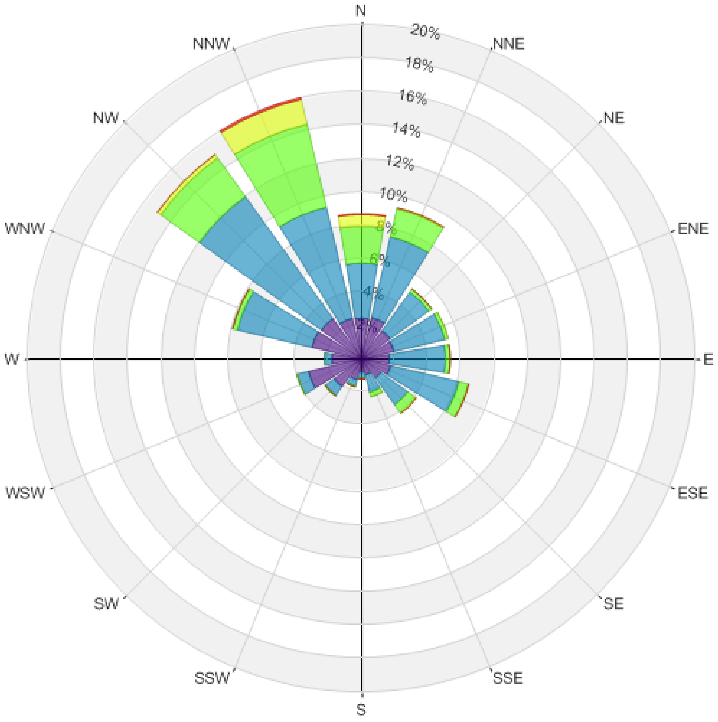
Winds in Shanghai – Summer



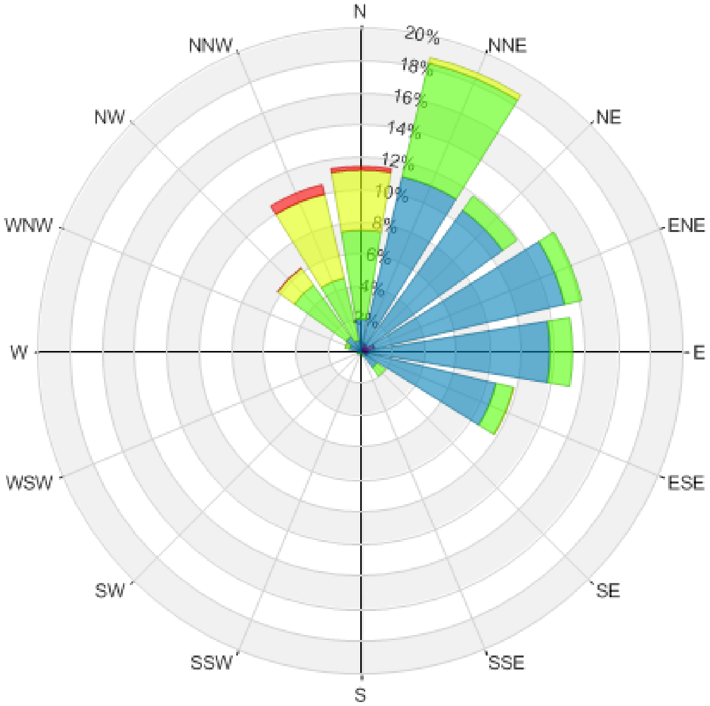
Southwest Monsoon
Northern Hemisphere Summer



Doha Misconceptions



Wind Rose for Doha All Seasons – Winds Blowing From (1992 – 2002)



Wind Rose for Doha Summer Afternoons – Winds Blowing From (1992 – 2002)

VERNACULAR STRATEGIES


HOT-HUMID


TEMPERATE

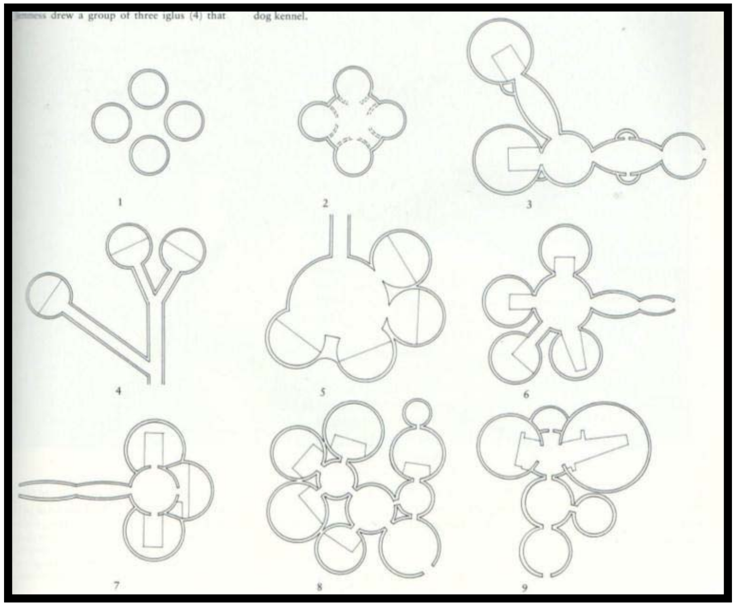

HOT-ARID


COLD

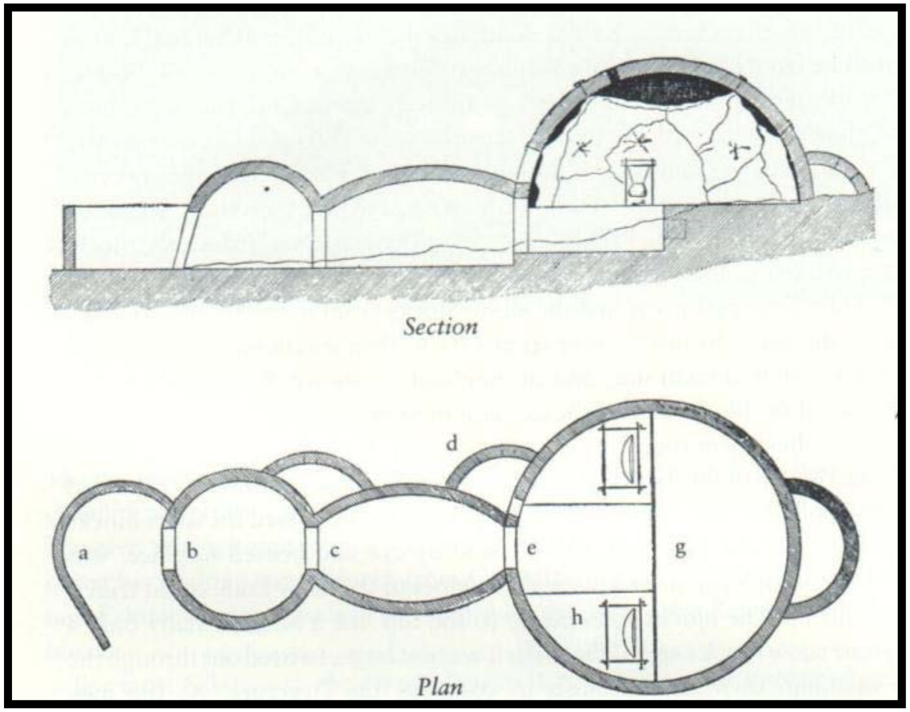
CLIMATE AS THE STARTING POINT

FOR RETHINKING ARCHITECTURAL DESIGN

Bio-climatic Design: COLD VERNACULAR



Native American Architecture



- Local materials
- Heat retention
- Vestibule
- Stratification

Bio-climatic Design: COLD RULES

Where **winter** is the dominant season and concerns for conserving heat predominate all other concerns. **Heating degree days greatly exceed cooling degree days**.

RULES:

- First **INSULATE**
- *exceed* CODE requirements (DOUBLE??)
- minimize infiltration (build tight to reduce air changes)
- Then **INSOLATE**
- **ORIENT AND SITE THE BUILDING PROPERLY FOR THE SUN**
- maximize south facing windows for easier control
- fenestrate for **DIRECT GAIN**
- apply **THERMAL MASS** inside the building envelope to store the FREE SOLAR HEAT
- create a sheltered MICROCLIMATE to make it LESS cold

YMCA Environmental Learning Centre, Paradise Lake, Ontario

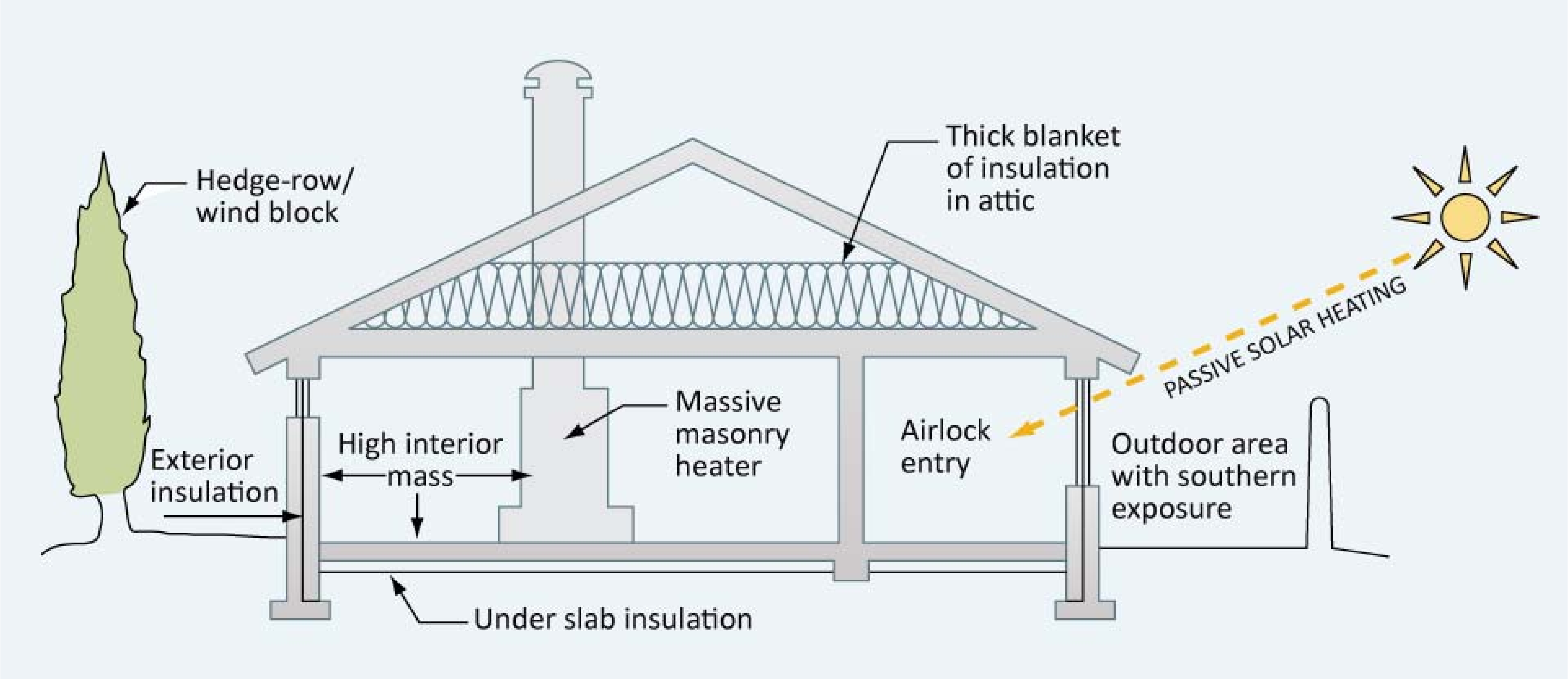
Cold Climate Passive Strategies

Characterized by long cold heating season with little or no need for summer cooling. **Heating degree days greatly exceed cooling degree days**.

Primary Passive strategies:

- Airlock entry
- Coniferous wind breaks
- Sheltered location
- High level of insulation
- Internal mass
- Passive solar heat
- Roof supports snow
- Super-insulated roof

Cold Climate Passive Strategies



Courtesy Baker-Laporte & Collette

Bio-climatic Design: HOT-ARID RULES

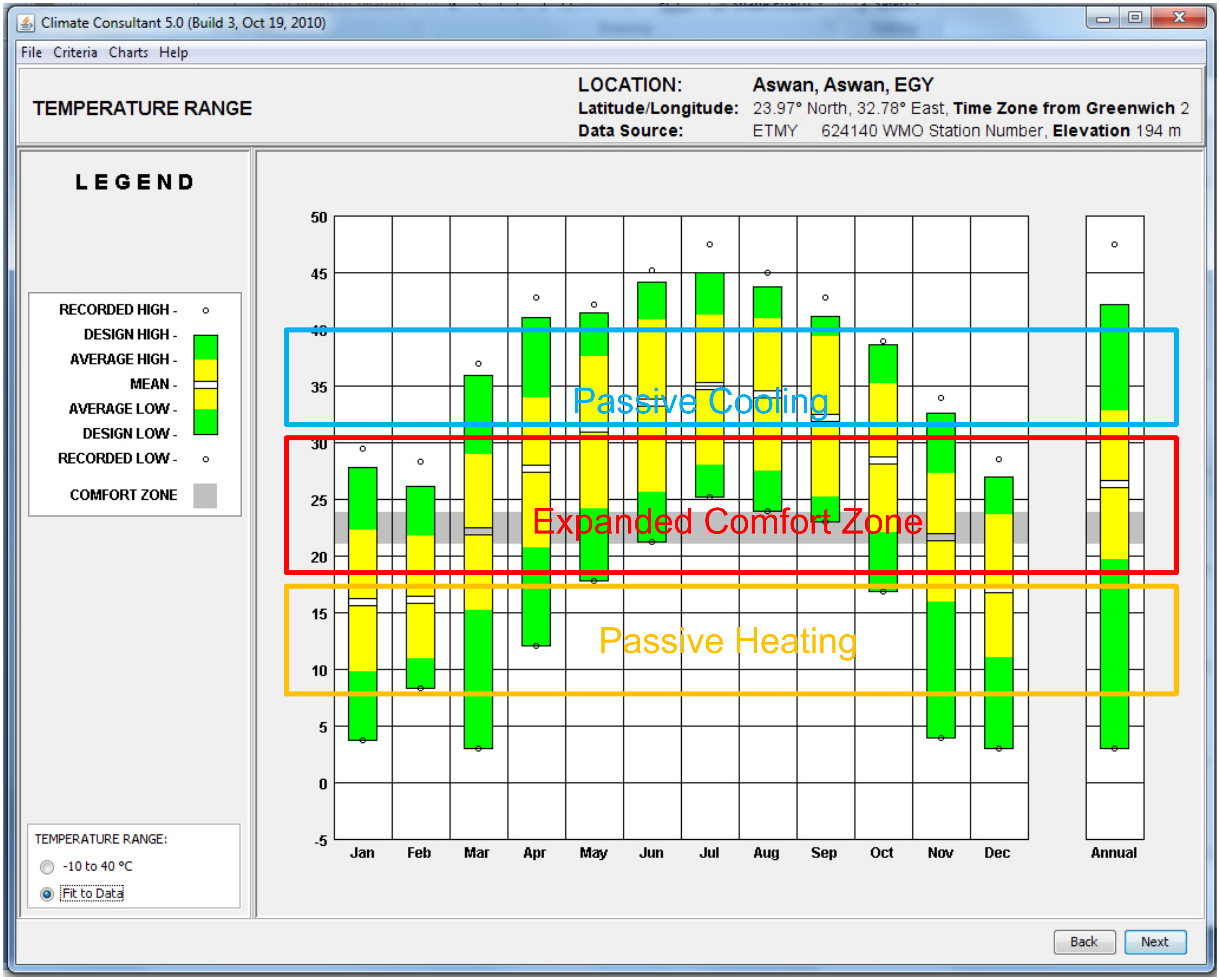
Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

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



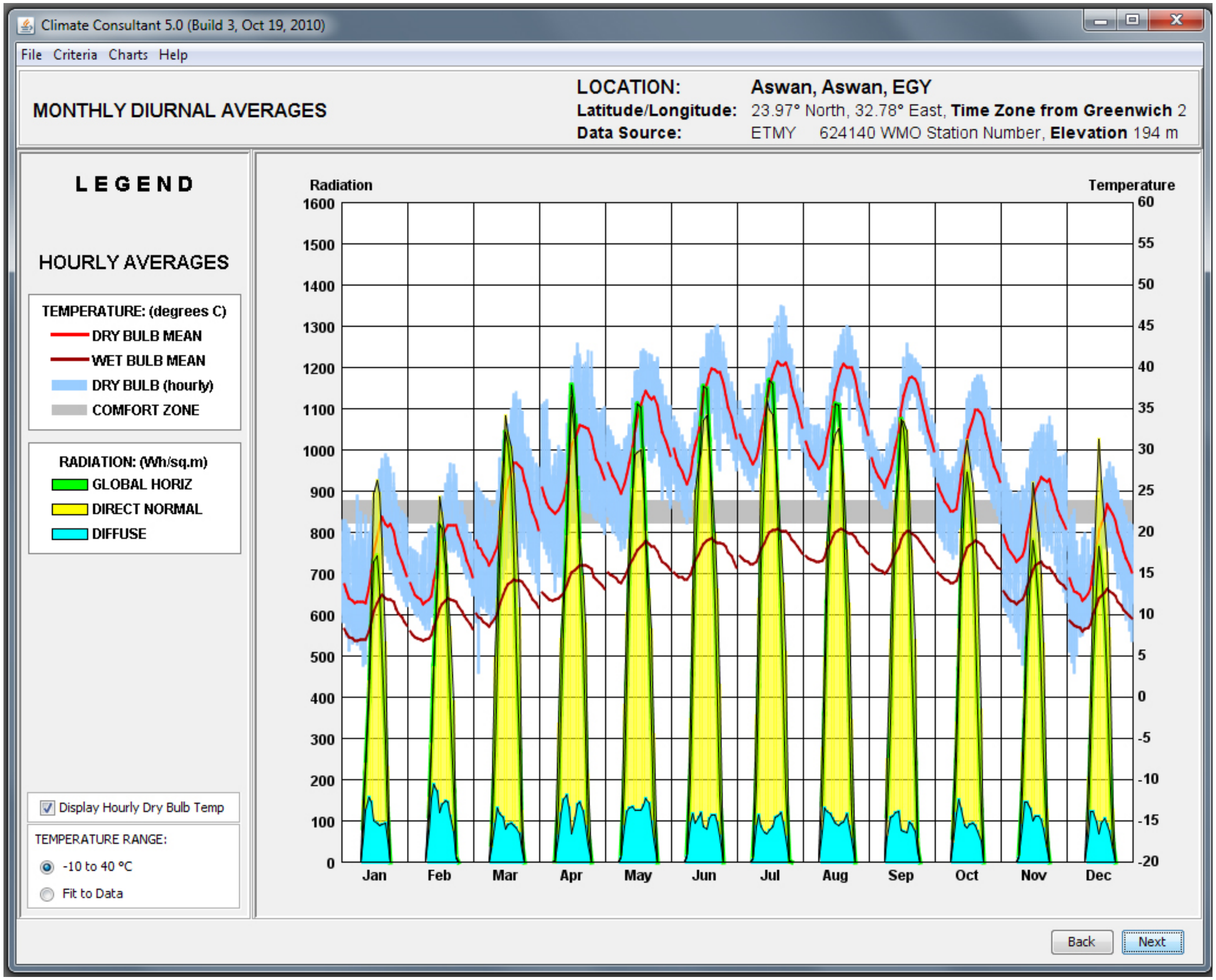
TEMPERATURE RANGE

LOCATION: Aswan, Aswan, EGY
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

RECORDED HIGH -	○
DESIGN HIGH -	🟩
AVERAGE HIGH -	🟨
MEAN -	▭
AVERAGE LOW -	🟨
DESIGN LOW -	🟩
RECORDED LOW -	○
COMFORT ZONE	⬜

TEMPERATURE RANGE:
○ -10 to 40 °C
● Fit to Data

Bio-climatic Design: HOT-ARID

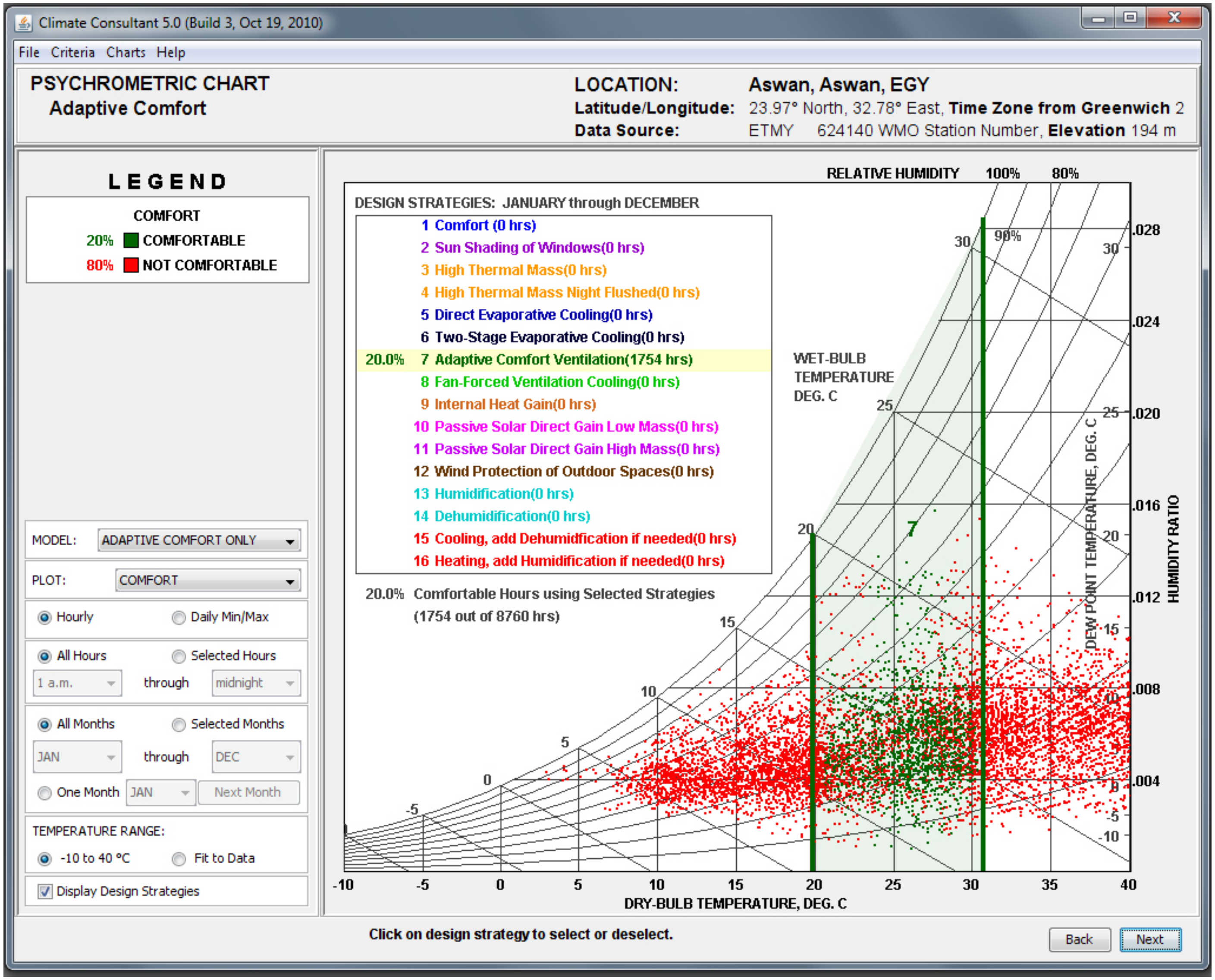


LOCATION: Aswan, Aswan, EGY
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
● -10 to 40 °C
○ Fit to Data

Bio-climatic Design: HOT-ARID



PSYCHROMETRIC CHART
Adaptive Comfort

LOCATION: **Aswan, Aswan, EGY**
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

LEGEND

COMFORT
20% 🟩 COMFORTABLE
80% 🟥 NOT COMFORTABLE

MODEL: ADAPTIVE COMFORT ONLY
PLOT: COMFORT
● Hourly ○ Daily Min/Max
● All Hours ○ Selected Hours
1 a.m. through midnight
● All Months ○ Selected Months
JAN through DEC
○ One Month JAN Next Month
TEMPERATURE RANGE:
● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

1 Comfort (0 hrs)
2 Sun Shading of Windows(0 hrs)
3 High Thermal Mass(0 hrs)
4 High Thermal Mass Night Flushed(0 hrs)
5 Direct Evaporative Cooling(0 hrs)
6 Two-Stage Evaporative Cooling(0 hrs)
20.0% 7 Adaptive Comfort Ventilation(1754 hrs)
8 Fan-Forced Ventilation Cooling(0 hrs)
9 Internal Heat Gain(0 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
11 Passive Solar Direct Gain High Mass(0 hrs)
12 Wind Protection of Outdoor Spaces(0 hrs)
13 Humidification(0 hrs)
14 Dehumidification(0 hrs)
15 Cooling, add Dehumidfication if needed(0 hrs)
16 Heating, add Humidification if needed(0 hrs)

20.0% Comfortable Hours using Selected Strategies
(1754 out of 8760 hrs)

Click on design strategy to select or deselect.

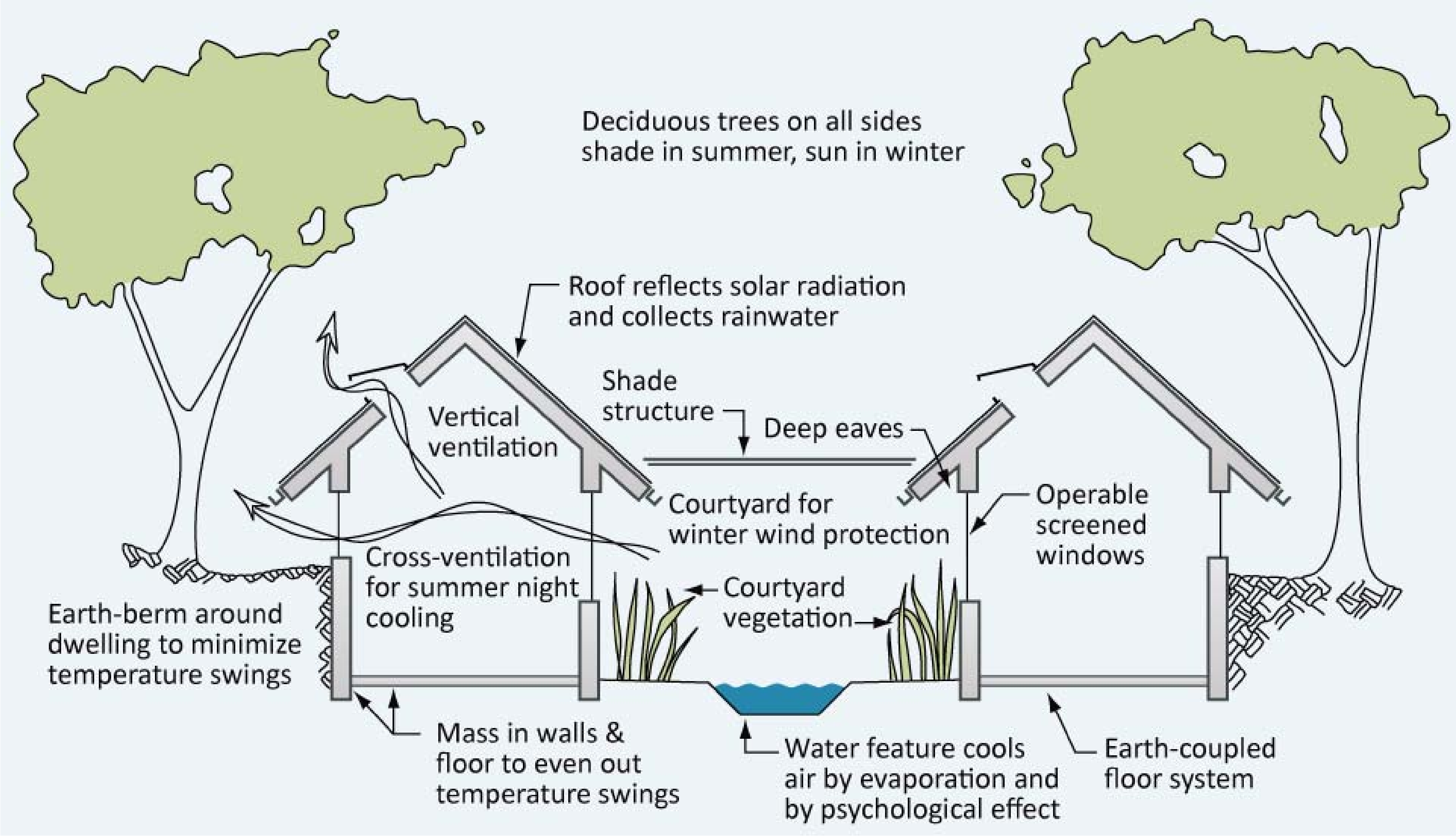
Bio-climatic: Hot-Arid Passive Strategies

High diurnal temperature swings, hot days, low humidity, **Cooling degrees days greatly exceed heating degree days.**

Primary Passive strategies:

- Earth coupled floor
- Earth bermed
- Mass walls & floors
- Cross ventilation
- Internal courtyard
- Evaporative Cooling
- Light color
- Reflective roof
- Tree shading
- Oriented to breezes
- Insulated roof
- Roof collects water

Bio-climatic: Hot-Arid Passive Strategies



Courtesy Baker-Laporte & Collett

Bio-climatic Design: HOT-HUMID

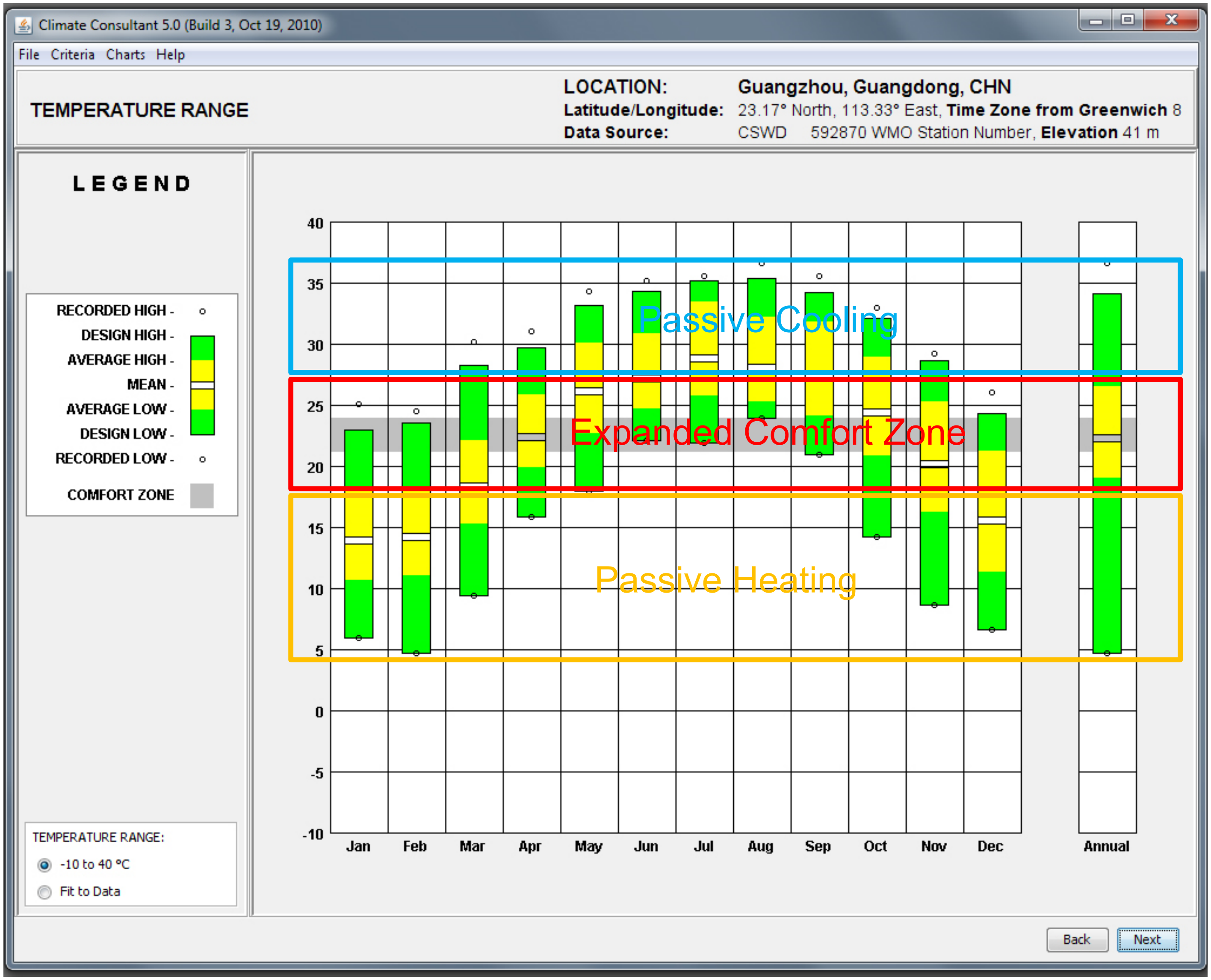
Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

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

House in Seaside, Florida

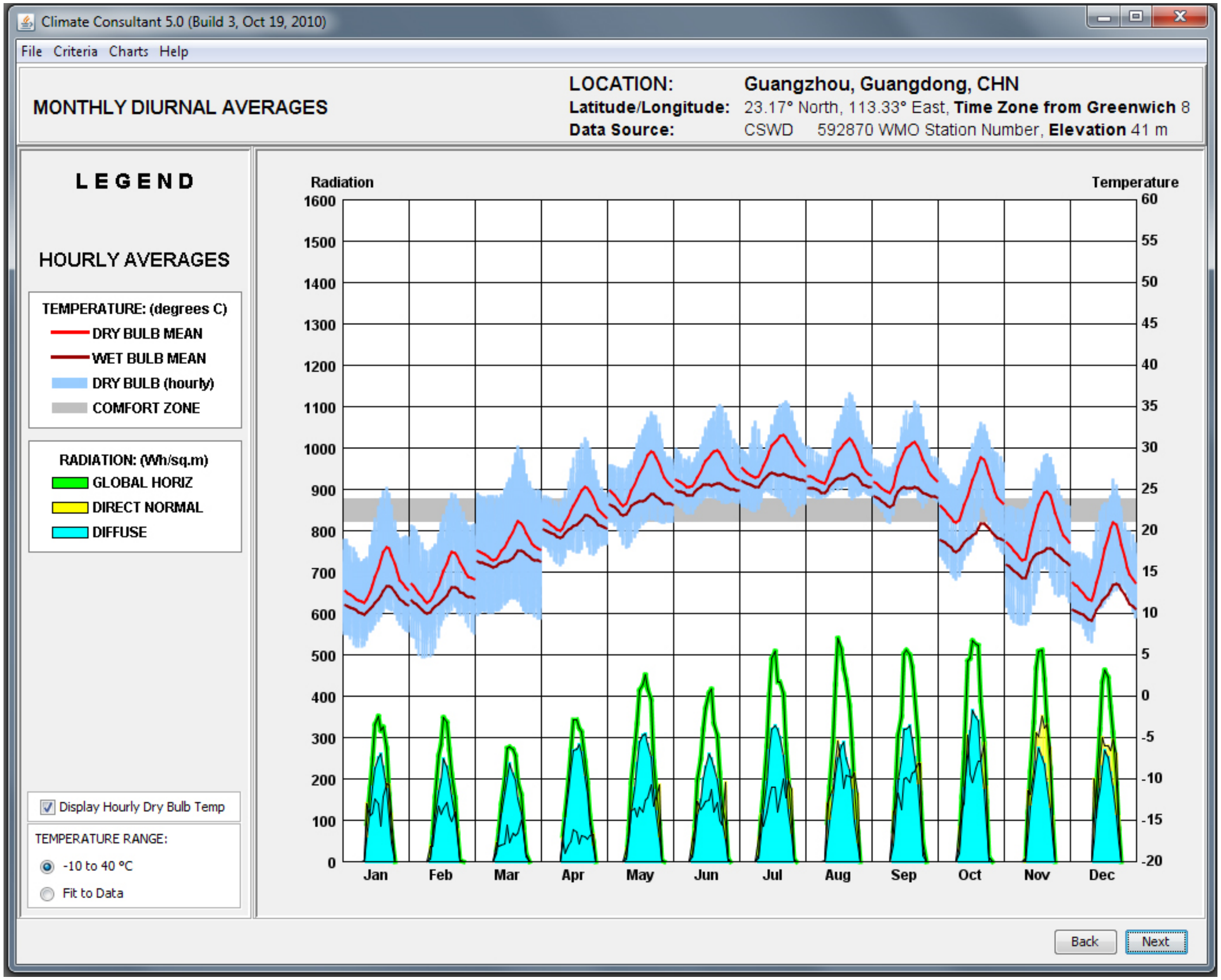
Bio-climatic Design: **HOT-HUMID**



LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8
Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

TEMPERATURE RANGE:
● -10 to 40 °C
○ Fit to Data

Bio-climatic Design: HOT-HUMID



MONTHLY DIURNAL AVERAGES

LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8
Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

HOURLY AVERAGES

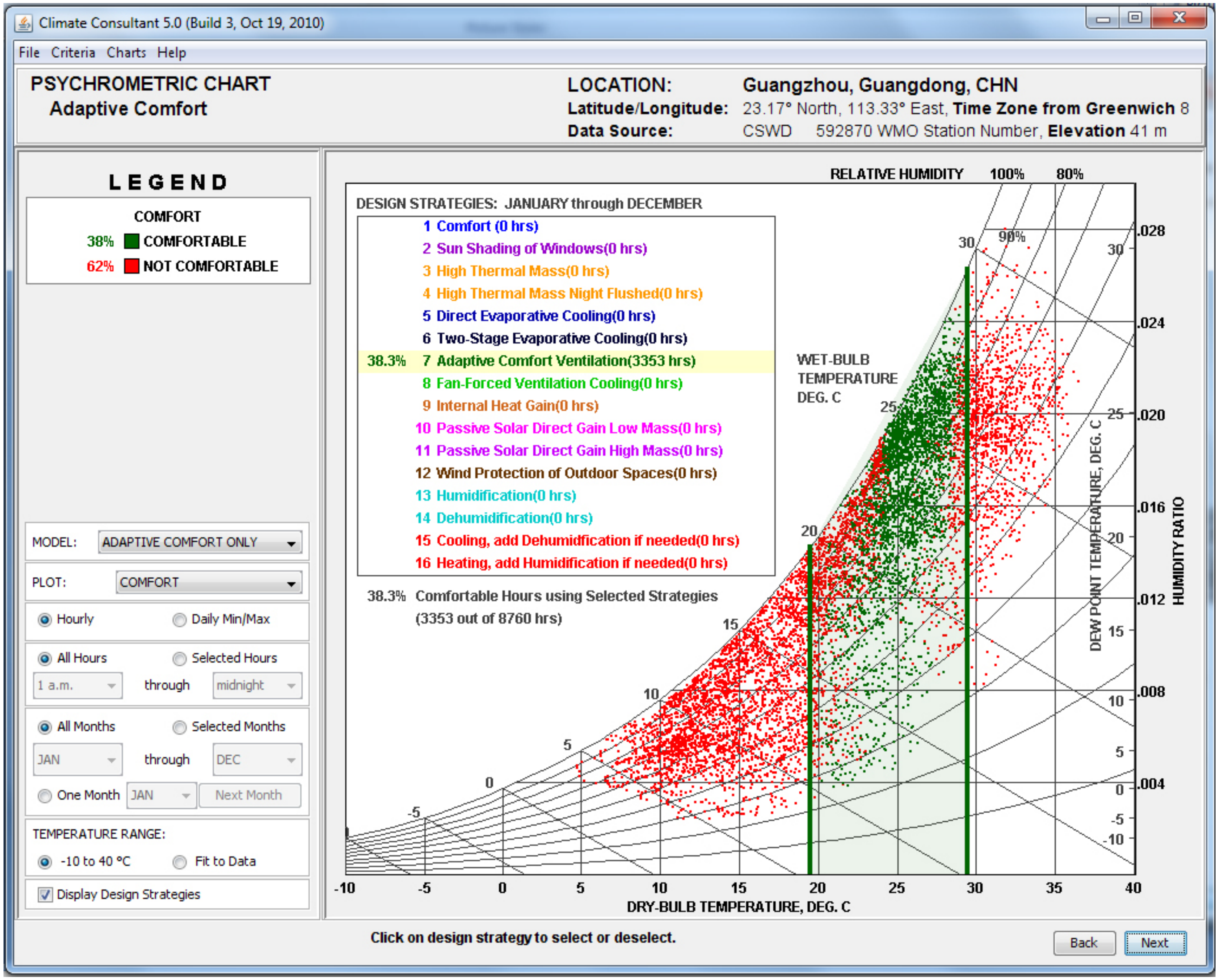
TEMPERATURE: (degrees C)
- DRY BULB MEAN
- WET BULB MEAN
- DRY BULB (hourly)
- COMFORT ZONE

RADIATION: (Wh/sq.m)
- 🟩 GLOBAL HORIZ
- 🟨 DIRECT NORMAL
- 🟦 DIFFUSE

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
- ● -10 to 40 °C
- ○ Fit to Data

Bio-climatic Design: HOT-HUMID



PSYCHROMETRIC CHART
Adaptive Comfort

LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8
Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

LEGEND

COMFORT
38% 🟩 COMFORTABLE
62% 🟥 NOT COMFORTABLE

MODEL: ADAPTIVE COMFORT ONLY
PLOT: COMFORT
● Hourly ○ Daily Min/Max
● All Hours ○ Selected Hours
1 a.m. through midnight
● All Months ○ Selected Months
JAN through DEC
○ One Month JAN Next Month
TEMPERATURE RANGE:
● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

1 Comfort (0 hrs)
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6 Two-Stage Evaporative Cooling(0 hrs)
38.3% 7 Adaptive Comfort Ventilation(3353 hrs)
8 Fan-Forced Ventilation Cooling(0 hrs)
9 Internal Heat Gain(0 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
11 Passive Solar Direct Gain High Mass(0 hrs)
12 Wind Protection of Outdoor Spaces(0 hrs)
13 Humidification(0 hrs)
14 Dehumidification(0 hrs)
15 Cooling, add Dehumidfication if needed(0 hrs)
16 Heating, add Humidification if needed(0 hrs)

38.3% Comfortable Hours using Selected Strategies
(3353 out of 8760 hrs)

Click on design strategy to select or deselect.

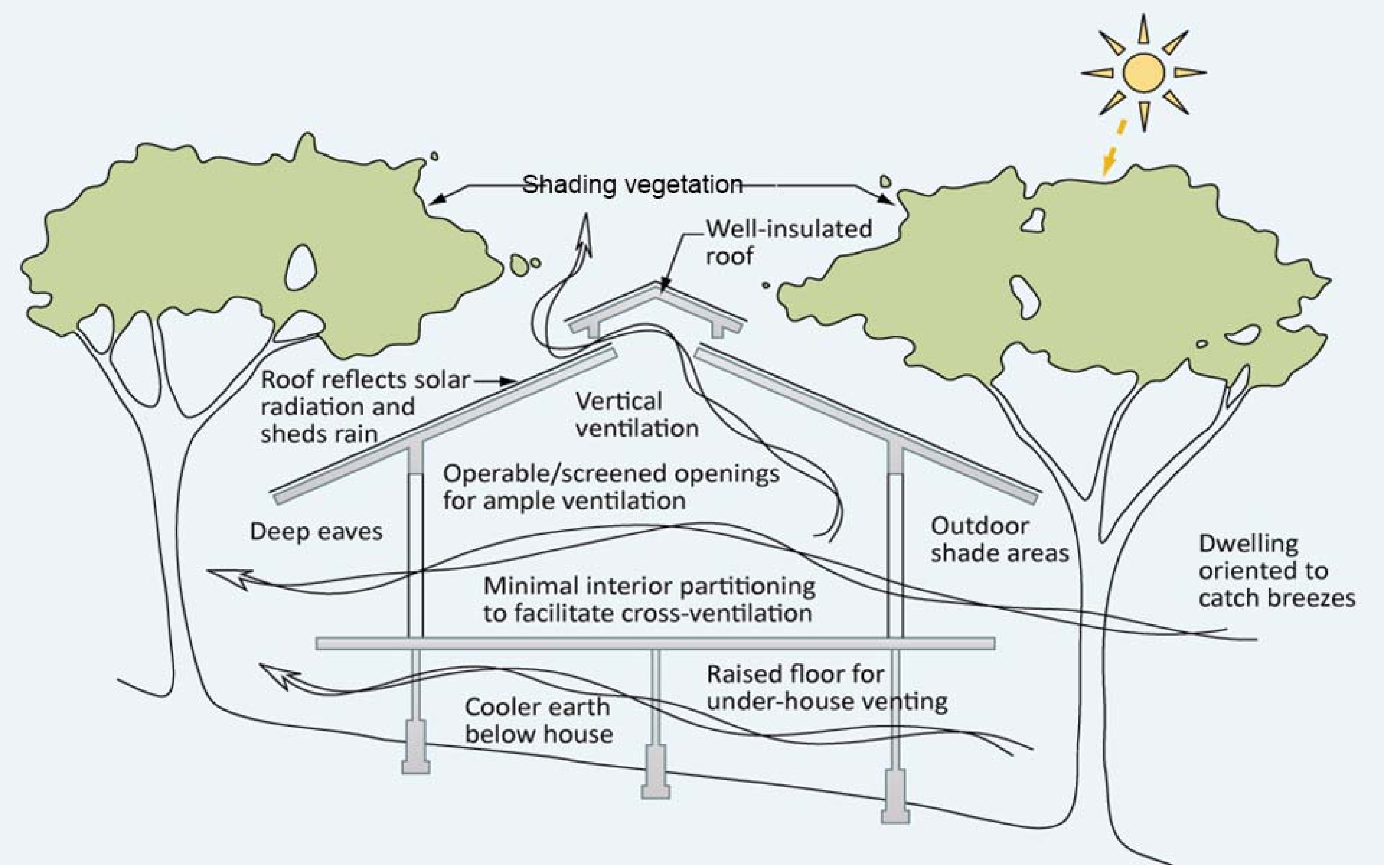
Bio-climatic Design: Hot-Humid Strategies

Low diurnal temperature swings, long cooling season, high humidity. **Cooling degrees days greatly exceed heating degree days.**

Passive strategies:

- Raised floor
- Cross ventilation
- Vertical ventilation
- Shading porches
- Light color
- Light materials
- Tree shading
- Oriented to breezes
- Insulated roof
- Reflective roof
- Roof sheds water

Bio-climatic Design: Hot-Humid Strategies



Courtesy Baker-Laporte and Collett.

Bio-climatic Design: TEMPERATE

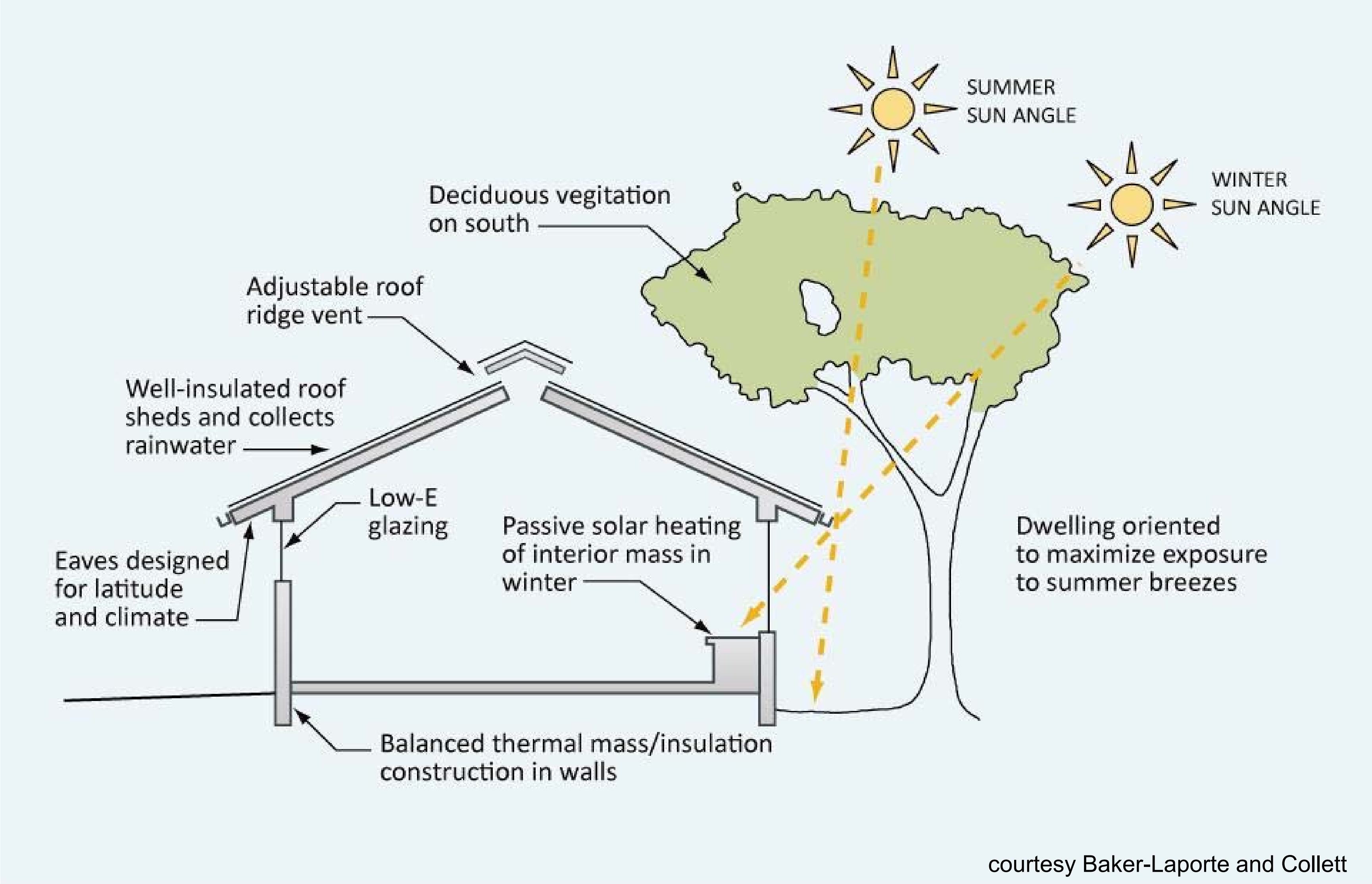
The summers are hot and humid, and the winters are cold. In much of the region the topography is generally flat, allowing cold winter winds to come in form the northwest and cool summer breezes to flow in from the southwest. **The four seasons are almost equally long.**

RULES:

- BALANCE strategies between COLD and HOT-HUMID
- maximize flexibility in order to be able to modify the envelope for varying climatic conditions
- understand the natural benefits of SOLAR ANGLES that shade during the warm months and allow for heating during the cool months

IslandWood Residence, Seattle, WA

Bio-climatic Design: Temperate Strategies



courtesy Baker-Laporte and Collett

CLIMATE RESPONSIVE

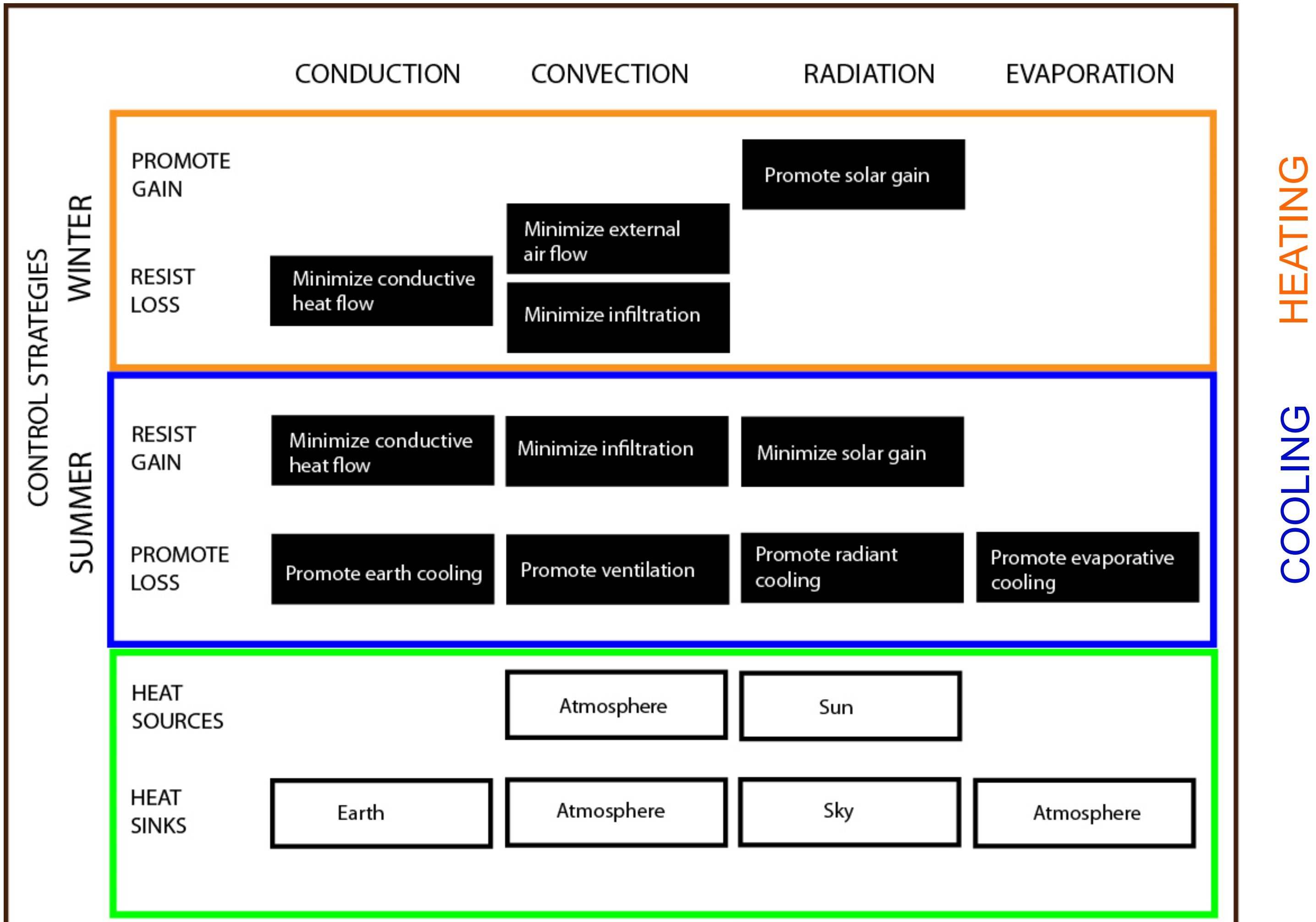
HEATING ↔ SUN

COOLING ↔ WIND

DAYLIGHTING ↔ LIGHT

PASSIVE STRATEGIES

Begin with Passive Strategies for Climate Control to Reduce Energy Requirements



CONTROL STRATEGIES

		CONDUCTION	CONVECTION	RADIATION	EVAPORATION	
WINTER	PROMOTE GAIN			Promote solar gain		HEATING
	RESIST LOSS	Minimize conductive heat flow	Minimize external air flow Minimize infiltration			
SUMMER	RESIST GAIN	Minimize conductive heat flow	Minimize infiltration	Minimize solar gain		COOLING
	PROMOTE LOSS	Promote earth cooling	Promote ventilation	Promote radiant cooling	Promote evaporative cooling	
	HEAT SOURCES		Atmosphere	Sun		
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere	

Strategies of Climate Control

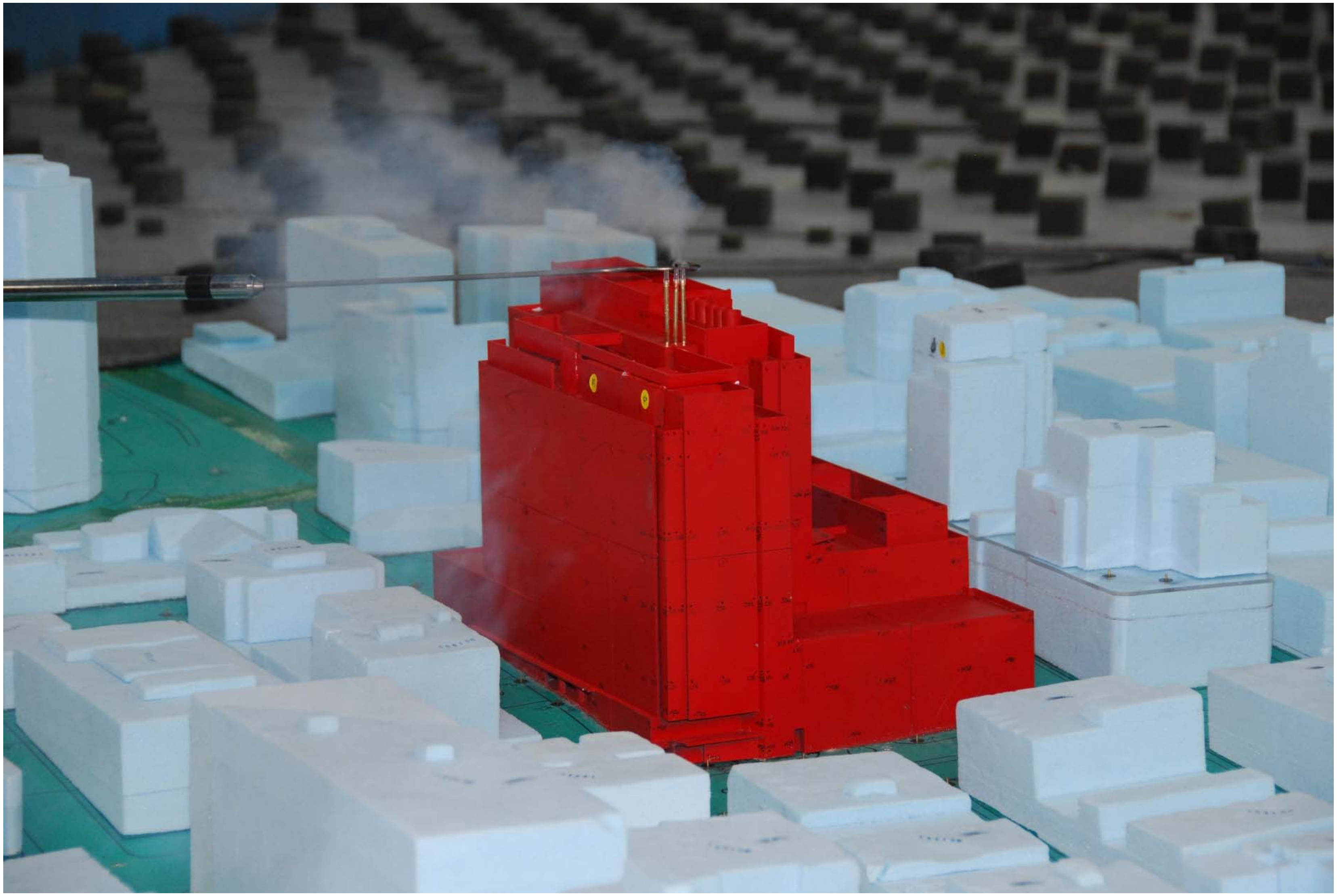
(chart modeled after Watson "Climatic Building Design")

Climate Engineering: A little about your trip to RWDI

Wind Tunnel

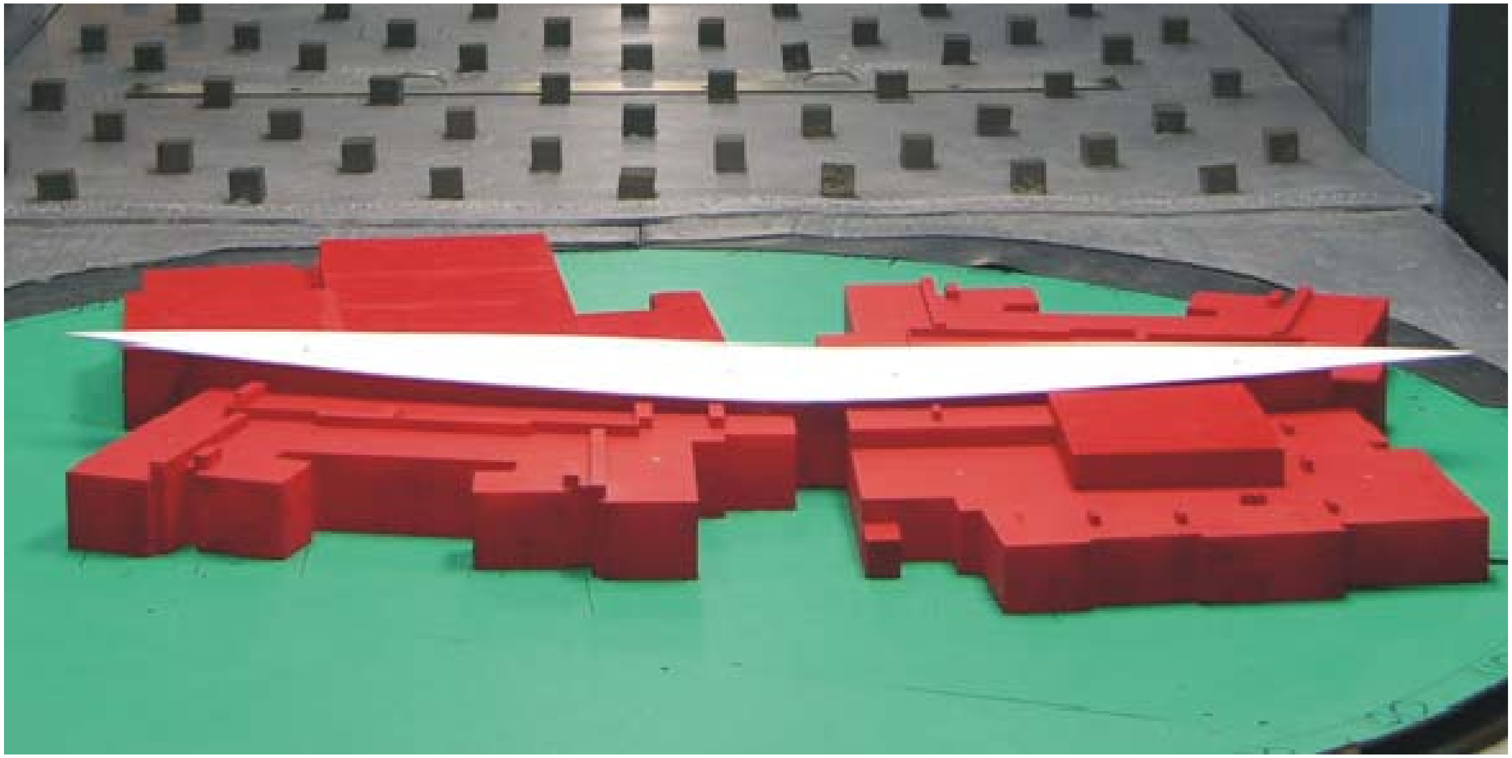
Wind Tunnel

Wind Tunnel

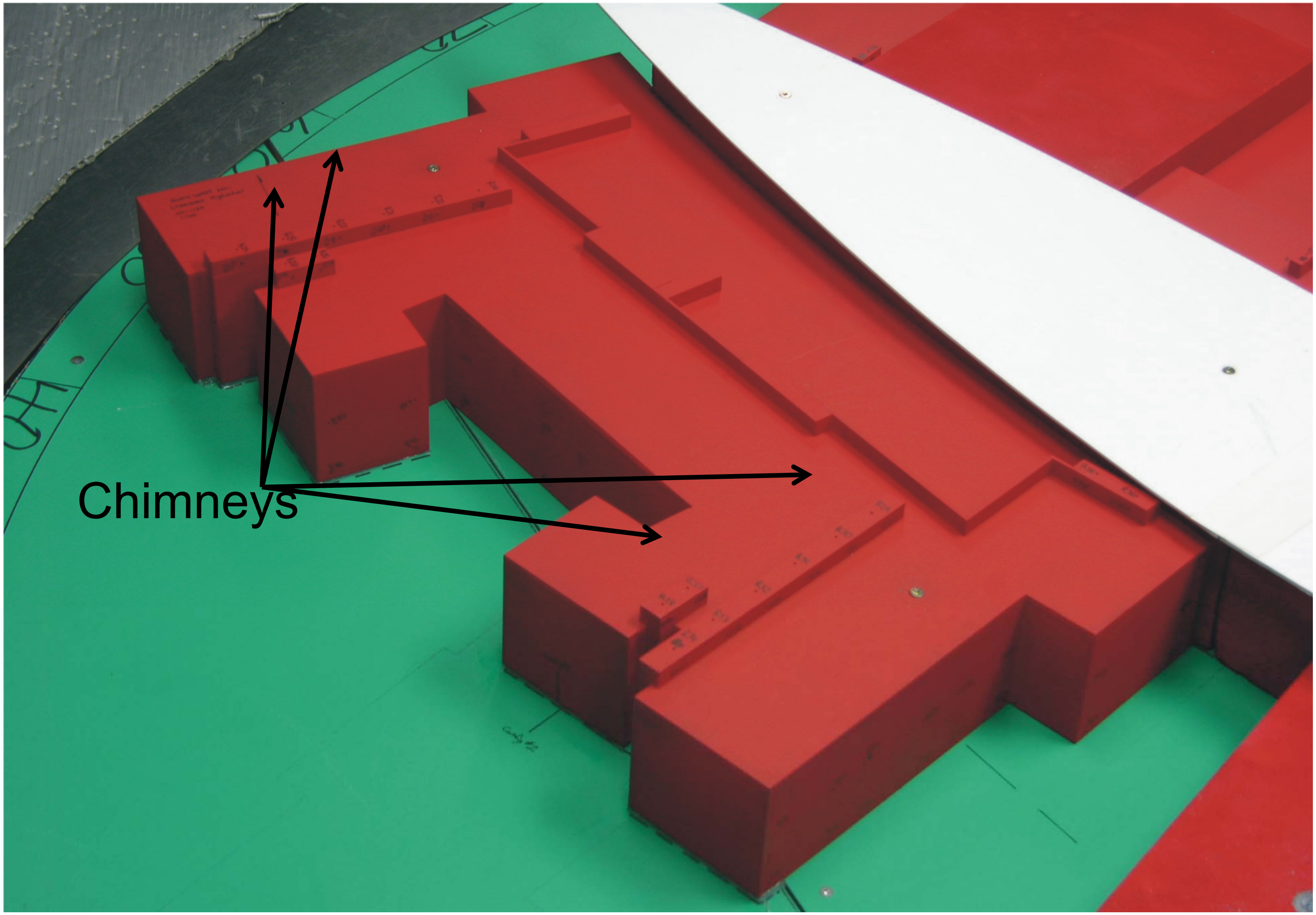


Wind Tunnel

Wind tunnel model



Windtunnel Measurements



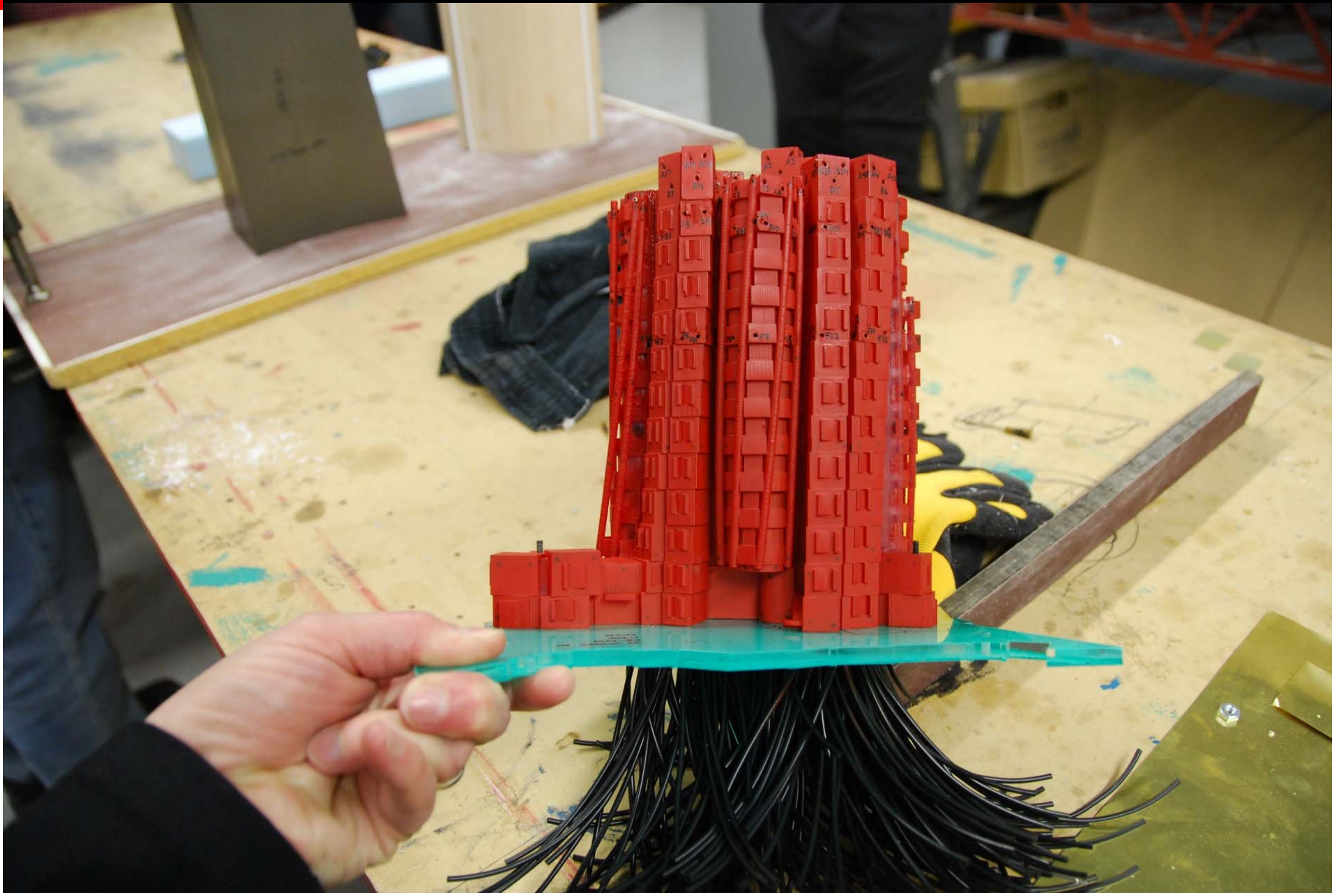
Chimneys

Urban situation easy to check

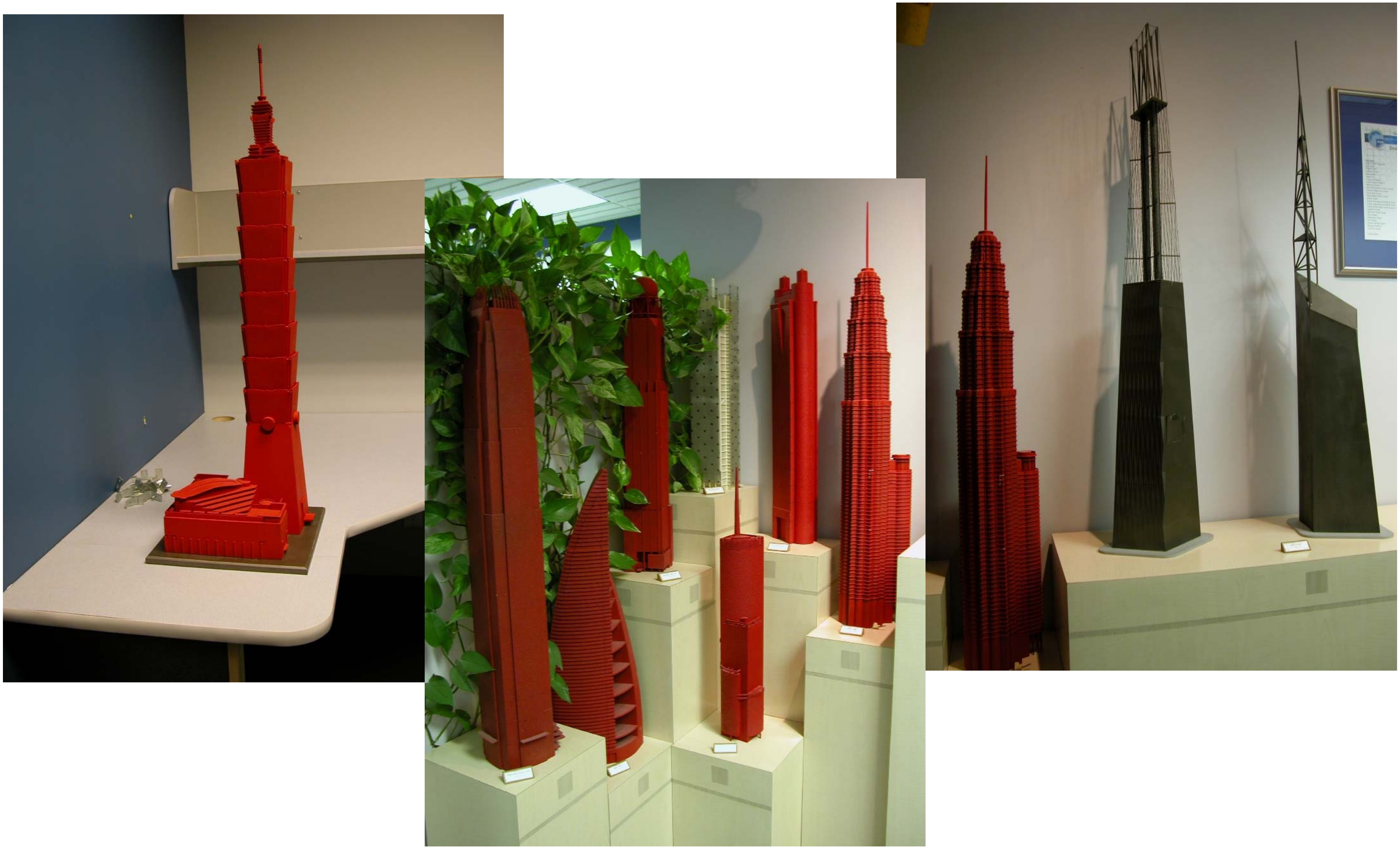
Models for the Leadenhall Building that include Swiss Re, previously modeled + site condition at base of buildings

Model Shop

Specially constructed models

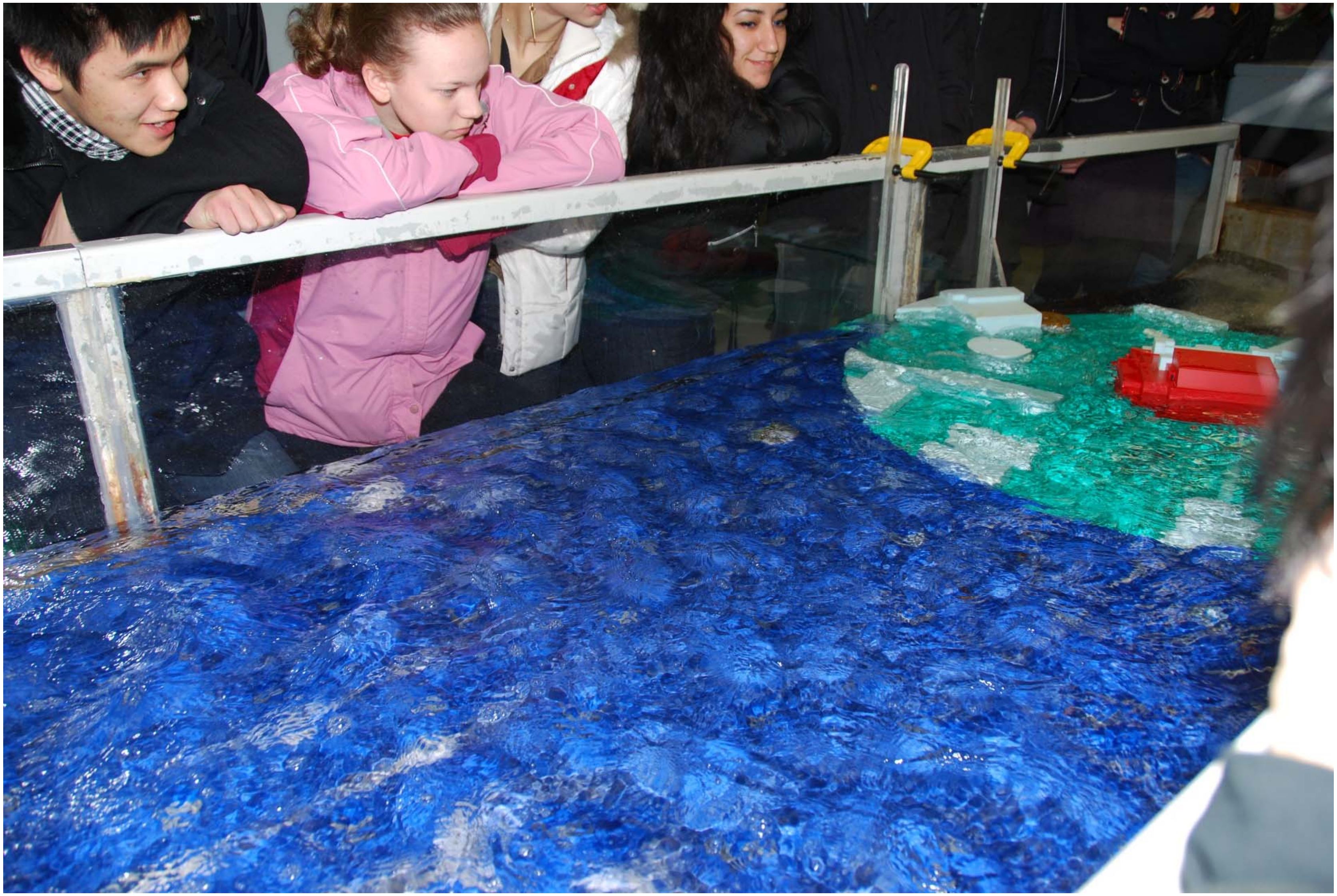


World class facility

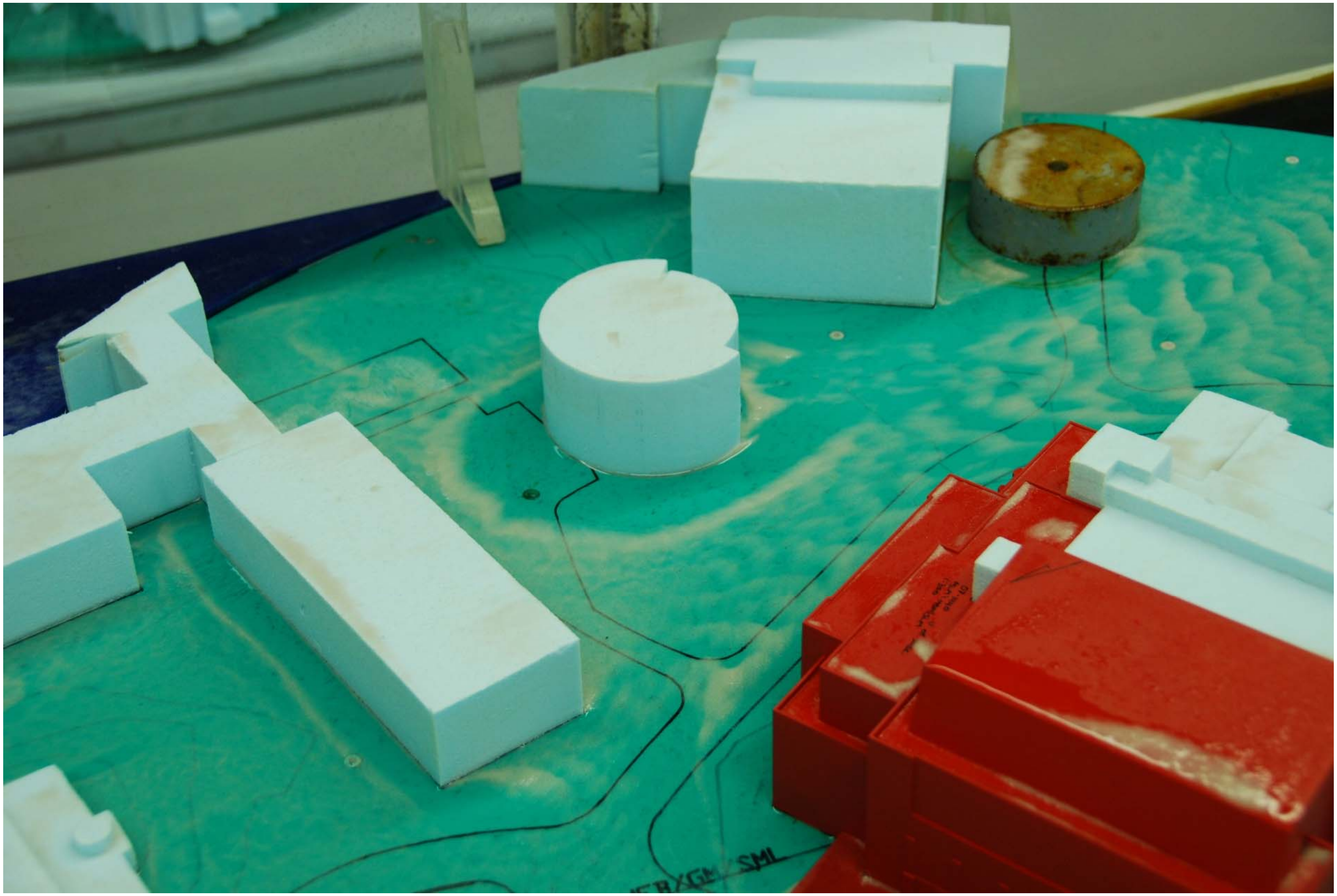


Water Flume

Water Flume



Water Flume



Seismic Testing

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